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THESIS

THE FEASIBILITY OF TESTING HAIR FOR ILLICIT DRUG USE IN THE UNITED STATES MARINE CORPS

by

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June 2003

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The purpose of this thesis was to examine the feasibility of testing hair for illicit drug use in the United States Marines Corps. Specifically, the study determined the hair test's potential for detecting and deterring illicit drug use and abuse among Marines. In addition, the study estimated the potential costs of implementing hair tests and examined fairness concerns with regard to testing hair among ethnically diverse populations. The results indicate that the hair test would be more effective than the urinalysis at detecting a wide variety of illicit drugs, with the exception of marijuana. The increased effectiveness of the hair test is likely to enhance the level of deterrence currently sustained by the Marine Corps' urinalysis program. Costs associated with the implementation of hair test would be offset by the increase in detection of illicit drug use and drug dependence among enlisted recruits and officer candidates pursuing active duty military service. Enhanced deterrence levels among active duty personnel that are a consequence of implementing the hair test would result in additional cost savings. Finally, implementation of the hair test would not result in racial bias, but may amplify the existence of drug preferences among different races.

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THE FEASIBILITY OF TESTING HAIR FOR ILLICIT DRUG USE IN THE UNITED STATES MARINE CORPS

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ABSTRACT

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I. INTRODUCTION

A. ENVIRONMENT

The United States Marine Corps' "zero tolerance" drug policy began in 1980 with the implementation of widespread urinalyses to detect the use of cannabinoids, opiates, cocaine, amphetamines, and other illicit drugs. The purpose of the program was to identify current drug users and deter future drug use. With significant documented success, the urinalysis program identified drug users and deterred drug use among Marines, thereby greatly reducing the use of illicit drugs throughout the Marine Corps. Studies suggest that the large decrease in drug use among service members since the implementation of a "zero tolerance" drug policy is primarily attributable to the urinalysis program.(Diddams, 1999; Martinez, 1998; McCrea & Hey, 2001) Although the use of drugs among Marines today is not as widespread as the 1970s and early 1980s, the Marine Corps maintains a coherent drug policy and continues to conduct urinalysis on a regular basis. Additionally, prospective Marines are screened for drug use history through questionnaires and an initial urinalysis prior to entering boot camp to ensure they do not have drug dependency issues or significant drug use backgrounds.

Recreational drug use continues to evolve; the popularity of some drugs diminishes while others become fashionable and available. Ecstasy is currently a popular drug among young adults and has become widely available to all portions of society worldwide. Urinalyses can only detect ecstasy use within three days after ingestion. Cocaine and derivatives of cocaine are also widely available and relatively affordable to the majority of young adults. Cocaine use can likewise be detected by urinalysis only within three days after ingestion. Marijuana is the most available and popular drug among young adults and is correspondingly the drug most often detected by the Navy and Marine Corps urinalysis program.(Past, 1999) The urinalysis has been successful at accurately identifying drug use within one month of ingestion. Since the implementation of the "zero tolerance" policy, the range of available drugs to young adults has increased, yet the urinalysis has remained the sole method of detecting illicit drug use.

Analysis of the molecular contents of hair is another means of detecting illicit drug use. Whereas urine is the medium carrying drugs and drug metabolites identified in a urinalysis, liquefied hair is the medium that carries drugs and drug metabolites identified in a hair test. Hair testing is becoming a widely used method of testing for drug use because of its ability to detect drug use for up to three months after ingestion. Hair tests can also identify a more accurate drug use history by pinpointing quantities of drugs used during a given period. Studies have shown that the use of hair is an extremely effective method of detecting the use of illicit drugs (Kintz, 1996). When compared to the urinalysis, the rate of detection with hair samples far supersedes that of urine samples for a wide variety of drugs. (Tagliaro, De Battisti, Lubli, Neri, Manetto, & Marigo, 1997).

Both the urinalysis and the hair test use the same scientific procedure known as radioimmunoassay (RIA) to screen for illicit drug use. RIA is a process where a testing medium (urine or dissolved hair) is introduced to a solution where radioactively labeled antigens bind with an antibody. The radioactively labeled antigens will bind with antibodies and produce a known quantity of binding instances; a radioactive counter can specifically count the number of binding instances, or complexes. If the labeled antigen were to test for marijuana use, for example, the labeled or radioactive antigen would be TCOOH, the metabolic compound produced from smoking marijuana. If urine or dissolved hair with TCOOH present is introduced into the labeled antigen and antibody environment, competition for the establishment of complexes will ensue. When the urine/hair TCOOH molecules (not radioactively labeled) create non-radioactive complexes, the number of countable radioactive complexes decreases. The radioactive counter can quantify the level of competition from outside agents (urine/hair) for a variety of antigen and antibody relationships. Testing for certain substances is dependent upon the specific antigen/antibodies used during the test.

Laboratories can further specify the quantity and presence of illicit drug molecules by use of a gas chromatography/mass spectrometry (GC/MS) regimen. The gas chromatograph separates chemical mixtures into their molecular form. Then the mass spectrometer creates gas-phase ions, separates the ions, and then counts the ions. A computerized library listing thousands of molecular signatures can then match the ionic structure of the tested compound. This is a very specific test that does not rely upon

separate and specific tests to determine the presence of an illicit drug. After a hair or urine sample undergoes RIA, the GC/MS procedure would be conducted to verify and precisely quantify the presence of illicit drugs. Currently, Navy drug laboratories will conduct a second immunoassay if the initial screening is positive. If the second immunoassay is positive, samples are tested and confirmed by GC/MS.(Past, 1999)

Some organizations have determined it to be in their best interests to use hair testing for illicit drug use screening for a variety of reasons. Some corporations, such as the Steelcase Corporation, chose to implement hair testing in order to avoid the costs associated with hiring a worker who has a significant drug use history.(Psychemedics, 2003) Other organizations, such as police units, use the hair analysis program to maintain the integrity and professionalism of their employees while deterring illicit drug use. Testing hair, in comparison to other body specimens, offers greater benefits for detecting a wide range of drugs and is therefore the focus of this study. The table below illustrates a general comparison of different techniques for the detection of amphetamines.

Table 1. Comparison of urine, sweat, saliva and hair for amphetamines analysis

Parameter	Urine	Sweat	Saliva	Hair
Sample collection	Privacy Concerns	Non invasive	Non invasive	Non invasive
Window of detection	2-3 Days	1 Week	Some hours	Some months
Associated problems	Adulteration	Limited sample	Limited sample	Environmental contamination

Adapted from "Determination of 'Ecstasy' components in alternative biological specimens" by P. Kintz and N. Samyn, 1999, Journal of Chromatography, 733, p. 138. Copyright 1999 Elsevier Science B.V.

The costs associated with implementing a hair test may, in the long term, be less than the urinalysis. Although a hair test is more expensive than a urinalysis, the deterrent effects would likely be significantly greater and the number of recruits with serious drug problems would likely be significantly less. McCrea & Hey (2001) suggest that, based on the costs of deterring and detecting drug users in the Navy, the urinalysis program

does not generate positive net benefits. Perhaps with more emphasis placed on the method of analysis with the implementation of hair testing, a positive net benefit can be generated. Studies have shown that there is a significant relationship between testing and deterrence, with the frequency of urine testing as the independent variable and deterrence as the dependent variable.(Martinez, 1998) It is possible then, that changing the independent variable from frequency of urine testing to the frequency of hair testing will significantly impact the magnitude of deterrence. No studies have yet been published that illustrate the impact of hair testing on deterrence. However, based upon the studies conducted with the impact of urinalysis on deterrence (Borack, 1997; Martinez, 1998), it can be reasonably hypothesized that a more effective test will lead to greater deterrence.

The Marine Corps' anti-drug policies may need revision to accommodate the evolving use of drugs and to counter gaming methods of current Marines. Hair testing addresses both the evolution of drug use among young adults and the gaming associated with urinalysis tests. The policy of "zero tolerance" mandates that all Marines who are tested positive for illicit drug use be processed for administrative discharge. Since the urinalysis only tests for the presence of illicit drugs, it cannot effectively determine the magnitude and frequency of drug use. A hair test can determine frequency and magnitude of drug use; thereby the ability to categorize drug users as one-time or heavy users is possible. A question that can be posed with the results of hair tests, as opposed to urinalyses, is at what level of drug use should the policy of mandatory discharge processing be implemented?

B. OBJECTIVE

The objective of this study is to examine whether testing hair is a feasible method for determining illicit drug use among Marines. Hair testing will be considered feasible if the following conditions are met:

1. Hair testing can effectively detect illicit drug use
2. Hair testing can effectively deter drug use
3. The costs of hair testing are comparable or less than the urinalysis
4. The hair test is fair to all Marines

Hair testing, a relatively new method for detecting illicit drug use, has some characteristics that can greatly contribute to the Marine Corps' effort to detect and deter drug use among Marines. This study will identify both the positive and negative characteristics of hair testing in order to assess whether the testing of hair is an option the Marine Corps can use with, or as a substitute for, urinalyses.

C. RESEARCH QUESTIONS

The primary research question is:

- Is hair sampling a feasible method for testing illicit drug use in the Marine Corps?

Secondary research questions include:

- Does hair testing effectively detect illicit drug use?
- Does hair testing effectively deter illicit drug use?
- Would the costs of hair analysis be more expensive than urinalysis for testing Marines
- Will the hair test be fair to all Marines?
- What policy changes may be appropriate if a widespread hair analysis is conducted in the Marine Corps?

D. SCOPE OF STUDY

Previous research suggests that the current Navy and Marine Corps urinalysis program significantly deters drug use.(Diddams, 1999; Martinez, 1998) Scientific research (Kintz, 1996) concludes that hair analysis results are significantly more accurate for detecting a wide variety of illicit drugs when compared to urinalysis. This study will examine whether hair testing, in lieu of or in addition to the urinalysis, would be a feasible method for detecting illicit drug use. When compared to the urinalysis, hair testing provides characteristics that may significantly increase the rates of drug detection and correspondingly increase deterrence. Since deterrence and detection provide the Marine Corps avoided costs attributable to drug use, hair testing may be more cost effective. This thesis will determine estimated changes in drug detection and deterrence percentages if the hair test is implemented. Then, the expected improvements in

deterrence and detection will be examined to ascertain their impact on the costs associated with the drug detection program, using the results of a previous urinalysis cost/benefit study as a reference. The results of hair tests have led some to perceive that the hair test is race biased. To determine whether hair testing would be fair to all Marines, scientific studies on race and gender bias (Kelly, Mieczkowski, Sweeney, & Bourland, 2000) will be examined to ascertain whether hair type has any impact on the results of a hair test. This study will examine whether hair testing in Marine Corps would be feasible, considering a limited budget and a large population of at-risk young adults of all races and genders.

E. LIMITATIONS

This feasibility study is conducted under the premise that the Marine Corps would be permitted to conduct hair tests independent of the other military services, including the Navy. This study also assumes that Navy drug laboratories in Norfolk, Virginia and San Diego, California would be funded to provide the training, manpower, and instrumentation necessary to effectively conduct the hair tests for the population of the Marine Corps. The increased costs of manpower, training, and instrumentation that are required to conduct the hair test are estimated to be 60% higher than the approximate $18 million dollar annual cost to administer the urinalysis program; an $11 million increase for a total cost of $29 million dollars annually. It is beyond the scope of this thesis to determine an actual cost of conversion from the urinalysis to the hair test; however, this cost increase is based upon a cost effectiveness study conducted by Pyschemedics Corporation, a leading company in hair testing. It is also beyond the scope of this study to determine the feasibility of collecting a 1.3cm portion of hair from the bodies of all Marines. It is assumed, for the purposes of this study, that all personnel subject to the test would be capable of providing several 1.3cm follicles of hair *from either their scalp or any other portion of their body.*

F. ORGANIZATION OF STUDY

Chapter II provides a review of relevant Department of the Navy policies and a review of the Marine Corps drug detection and deterrence program. Chapter III is a review and analysis of relevant studies on the effectiveness hair testing in detecting illicit drugs. Chapter III will also investigate the hair test racial bias controversy and analyze studies examining race bias issues and drug testing. Chapter IV will review and analyze the studies on the deterrent properties of the hair test. Hair test characteristics and urinalysis characteristics will be compared in Chapters III and IV in order to determine hair test levels of detection and deterrence, relative to those levels currently achieved by the urinalysis. Results of urinalyses and hair tests, characterized by race and hair color, are compared to determine whether the hair test results are proportionally different than the urinalysis for the detection of different drugs among races. Estimated ranges for the values of the following listed items will be developed in Chapter III and IV to quantify the impact a hair test would have on the effectiveness of the Marine Corps' drug detection policies:

1. Probability of detection
2. Percentage of drug users detected
3. Detection factor
4. Percentage of actual drug users, accounting for under-reporting, based on 1995 DODWWS data

Chapter V will examine estimated cost and benefit outcomes of implementing the hair test, based upon a cost estimate study conducted on the Navy's urinalysis program and the enhanced detection and deterrence characteristics of the hair test developed in Chapter III and IV. Chapter VI will provide conclusions and recommendations for future studies.

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II. ORDERS AND DIRECTIVES FOR DRUG ABUSE AND TESTING POLICY

The goal of this research is to determine whether the testing of hair is a feasible method of drug detection for the Marine Corps. Many studies have illustrated the comparative advantages of hair testing over the urinalysis for individuals or small organizations.(Mieczkowski, 2001) This study will examine whether it is feasible for the Marine Corps to implement hair-testing measures to enhance its drug detection and drug deterrence efforts in a fair and cost-effective manner. Although the Marine Corps' drug detection policy directly reflects the Department of the Navy drug detection policy, it is assumed for the purposes of this study, that the Marine Corps would be approved to institute drug detection procedures that are different than those currently approved by the Department of Defense and the Department of the Navy.

On 25 August 1980, DoD Directive 1010.4, "Drug and Alcohol Abuse by DoD Personnel," was issued. DoD Directive 1010.4 formalized the policy that established drug abuse as incompatible with military service and required Military Services to process drug abusers for separation. The current directive establishes the definitions for drug and alcohol abuse, establishes broad DoD policy, and designates responsibilities for the drug enforcement policy. The directive has been periodically updated, but remains the primary policy for drug and alcohol abuse prevention. According to DoD Directive 1010.4, the DoD policy for drug and alcohol abuse is "To prevent and eliminate drug and alcohol abuse and dependence for the Department of Defense" and that "Such abuse and dependence are incompatible with the readiness, the maintenance of high standards of performance, and military discipline."(p. 3)

DoD Directive 1010.4 defines drug abuse as "The wrongful use, possession, distribution, or introduction onto a military installation of a controlled substance, prescription medication, over-the-counter medication, or intoxicating substance (other than alcohol). 'Wrongful' means without legal justification or excuse, and includes use contrary to the directions of the manufacturer or prescribing healthcare provider, and use of any intoxicating substance not intended for human ingestion." (p.2) The broad range

of substances that can lead to someone being a drug abuser, as outlined by this definition, can include unique or long-term use of inhalants such as model airplane glue, naturally grown herbs and mushrooms, or illicit drugs such as cocaine, opiates, LSD, cannabanoids, and amphetamines. DoD Directive 1010.4 further states that commanders will "counsel, discipline, and/or process drug abusers for separation."(p.4). The Navy/Marine Corps urinalysis program only tests for cocaine, LSD, cannabanoids (hashish/marijuana), and amphetamines. Fifty percent or less of the samples received by Navy drug laboratories are randomly tested for PCP, barbiturates, and opiates.(Past, 1999)

DoD Directive 1010.1, "Military Personnel Drug Abuse Testing Program," dated 28 December 1984, established policy and responsibilities for the urinalysis programs of all Military Services. DoD Directive 1010.1 has been updated on 11 January 1999, but remains the primary directive for urinalysis policy. Beside policy and responsibilities, the directive establishes circumstances for urinalysis testing and details how results of urinalysis may be used. The following mandates of DoD policy, as outlined in DoD Directive 1010.1, are of most relevance to this study:

1. Use drug testing to deter Military Service members, including those members on initial entry on active duty after enlistment or appointment, from abusing drugs (including illegal drugs and other illicit substances)

2. Use drug testing to permit commanders to detect drug abuse and assess the security, military fitness, readiness, good order, and discipline of their commands

3. Use drug testing as a basis to take action, adverse or otherwise (including referral for treatment), against a Service member based on a positive test result.

4. Recognize the illicit use of anabolic steroids by military members as an offense under the Uniform Code of Military Justice (UCMJ)...and treat that use in the same manner as other illicit drug use.

(DoDD 1010.1, 1999, p. 2)

DoD Directive 1010.1 directs the Secretaries of the Military Departments to operate drug-testing facilities that meet testing requirements. Also, the Military Departments are directed to test, at a minimum, one random sample per active duty member each year (DoDD 1010.1, 1999, p. 7).

The only officers authorized to initiate a drug test are Commanding Officers and Medical Officers.(MCO P1700.24B, 2001) Beside the random urinalyses that MCO P1700.24B (2001) directs be conducted on 10% of each unit population per month, there are a variety of other reasons for initiating a urinalysis. The reasons a Commanding Officer or Medical Officer may initiate a urinalysis are listed below (MCO P1700.24B, 2001).

1. Consensual. A Marine is suspected of having used illicit drugs is asked to consent to a urinalysis, according to consent search procedures established in Military Rules of Evidence.

2. Probable Cause. A Marine is suspected of having used illicit drugs and a drug test is ordered because it is believed that the test will provide evidence of the offense.

3. Inspection. Either a random selection of members of a units or a "unit sweep" of all members of a unit. Probable cause is not required. Conducted on a regular basis to act as a deterrent.

4. Accession Testing. All officer candidates and recruits are tested within 72 hours of arriving at their training site. Candidates or recruits who refuse testing or those who are found to be positive for drugs will be processed for separation. Those found to have been dependent on drugs would have their appointment or enlistment voided.

5. Command Directed. A Commanding Officer may authorize a drug test for a specific Marine when his/her behavior or conduct "gives rise to a reasonable suspicion of drug abuse." A drug test may also be ordered to determine whether a Marine is competent for duty or needs counseling, rehabilitation, or treatment.

6. Physician Directed. A Medical Officer may order a drug test to determine competence of duty or for any other valid medical reason based upon suspected drug abuse.

7. Official Safety, Mishap, Accident Testing. Drug test authorized for the purpose of accident investigations.

8. Rehabilitation/Treatment. Drug tests taken while a Marine undergoes continued counseling and rehabilitation to monitor drug abuse recurrence.

9. Service Directed. Drug tests directed by the Secretary of the Navy or the Commandant of the Marine Corps for individuals involved in the urinalysis program, security personnel, re-enlistments, parolees, and Marines checking-in from leave, temporary duty, or transfers from other units.

After a urinalysis is taken, the urine specimens are mailed to the Navy Drug Screening Laboratory in Jacksonville, Florida or San Diego, California. The drug screening laboratory will screen the urine for the drugs mentioned above and report positive results to the originating unit and Headquarters, Marine Corps by naval message within approximately one week.(Past, 1999). The consequences of a Marines being reported as an illegal drug abusers are mandatory processing for administrative separation from the Marine Corps, possible non-judicial punishment or court martial, and drug dependence screening. Drug abusers are "screened at a [Substance Abuse Counseling Center], referred to a Medical Officer for diagnosis, and provided treatment prior to separation, if warranted."(MCO P1700.24B, 2001, p. 3-20) Although MCO P1700.24B (2001) mandates that all drug abusers will be *processed* for administrative separation, it does not mandate actual separation. This gives commanders the ability to request the retention of some drug abusers with high potential who, although processed for administrative discharge, have received favorable recommendations from their chain of command requesting that they not be discharged.

III. HAIR TESTING DETECTION EFFECTIVENESS AND EXAMINATION OF RACIAL BIAS

This chapter will explore the process of hair testing and whether it can effectively detect drug use in a manner that is fair to all Marines. To determine this, a variety of studies that investigate the efficacy of the hair test in detecting a wide variety of illicit drugs will be reviewed. Studies that provide comparative results of the hair test and urinalysis will be reviewed and analyzed to develop estimated differences in the detection properties of the hair test relative to the urinalysis. The effect of gaming on the hair test and urinalysis will be examined to determine whether gaming can adversely impact the overall effectiveness of either the urinalysis or hair test. Since the hair test uses a different testing medium than the urinalysis, an analysis of studies that investigate the issue of race bias with the hair test will be conducted to determine whether the hair test would be fair to all Marines.

A. DESCRIPTION OF HAIR TESTING PROCESS AND PROCEDURES

The method of testing hair for ingested substances is not a new innovation. "More than 130 years ago, J.L. Casper reported in Praktisches Handbuch der gericchlichen Medizin the identification of arsenic in human hair recovered from a cadaver exhumed after more than a decade of internment. Imwinkelreid (1991) has noted that American courts first accepted testimony on hair analysis as a forensic entity in 1882 [Knoll v. State, 55 Wis. 249, 12 N.W. 369]. Psychoactive compounds were first recovered from hair when the successful assaying of guinea pig fur for barbiturates was reported by Goldblum, Goldbaum, and Piper (1954)."(Mieczkowski, 2002, p. 100) Recently, many studies have been conducted to determine the efficacy of determining illicit drug use in humans. There is little debate among scientists that detecting drug use through the analysis of hair is an effective means. However, there is considerable debate among scientists and within society in respect to the interpretation of the results of hair analysis. The three primary disputes involve washing techniques to remove external contamination, variations in hair color and texture that may lead to race bias, and

established standards for cut-off levels.(Mieczkowski, 2002) Scientific studies, conducted in controlled environments and published in creditable journals, will be the basis of this study to illustrate the effectiveness of hair testing.

The methods scientists use to test hair can be quite different. There exists no established standard among scientists for the three primary processes used to test hair: preparation of hair samples, initial screening, and confirmation. However, scientists at the Clinical Biochemistry Labortatory, Ca' Granda Niguarda Hospital in Milan, Italy have tested the hair of thousands of subjects for driving license applications and recommend guidelines and basic requirements for laboratories. The three main points can be summarized as: (a) laboratories must have one year of experience with hair testing; (b) the analysts must be adequately trained; and (c) positively screened tests must be confirmed by GC/MS.(Cassani, Da Re, Giuliani & Sesana, 1997, p.23)

Although clinical processes vary, several generally accepted methods are used for the determination of drug use. The first process, hair preparation, includes washing hair to remove residues from the environment that can lead to false positives. The next step, initial screening, is conducted to separate negative specimens from those specimens that *may* be positive for drugs or drug metabolites. Radioimmunoassay (RIA) is the technique used by most scientists for the initial screening process. In fact, RIA is the technique currently used in laboratories with urine specimens. If the presence of drugs or drug metabolites is discovered with RIA, the same sample will be tested again using gas chromatography or mass spectrometry (GC/MS)—an entirely different process using different testing equipment. Both RIA and GC/MS are widely accepted methods for testing hair and provide strong evidence of the presence of drugs or their metabolites. Unless otherwise specified in this study, the process of testing hair for all studies listed below will be washing, initial screening by RIA, and confirmation by GC/MS.

B. REVIEW OF STUDIES ON THE EFFICACY OF HAIR TESTS

Italian law prohibits issuing a driving license to drug addicts and others who may have a substantial risk of relapse. For this reason, the Italian government initiated hair sampling to determine whether previous drug addicts have abstained from using illicit

drugs prior to their being approved for a driving license. Much literature on the effectiveness of hair testing, therefore, comes from studies conducted on human subjects in Italy since 1995. Italian researchers have had much experience in processing thousands of hair samples over the past fifteen years without a private profit motive, so their research should be generally viewed as complete and without bias.

In their article, "Integrated use of hair analysis to investigate the physical fitness to obtain the driving license: a casework study," Tagliaro et al (1997) determined that "the slow clearance of cannabinoids from the body assures a sufficiently wide detection window even with urine testing. On the other hand, the very low concentrations present in the hair hamper the development of simple, routine analytical methods and lead to the risk of misinterpretation of results due to passive exposure to cannabis or cannabis derivative smoke."(p. 135) Tagliaro et al (1997) conclude in their article that "hair analysis, if not used as a stand alone assay but integrated with repeated urinalyses, is highly effective and reliable in discovering drug abuses in the population, particularly when recreational patterns of use (not typical addiction and dependence) are to be investigated."(p. 135)

Spiehler (2000) corroborates Tagliaro et al's findings about the inefficiency of hair analysis in regard to marijuana detection. She states that most immunoassays detect THCOOH, the metabolite of marijuana chemicals commonly found in urine; however, the presence of THCOOH is only found in low concentrations in the hair.(Spiehler, 2000, p. 253) Spiehler (2000) also suggests that hair testing is not appropriate for testing recent drug use because a detectable amount of any drugs in the hair will not be incorporated into the hair shaft until at least a week after intake. Therefore, in a situation where there is reason to believe a person is under the influence of an illicit drug, it would not be practical to give the person a hair test until a week or two after possible drug use is identified. The urinalysis, however, would be able to detect recent drug use and would be more appropriately used in the specific situation where it is necessary to identify recent drug use.

The fact that hair analysis is not the best method of testing for marijuana use is supported by Tom Mieczkowski (2002) in his article, "Does ADAM need a haircut? A

pilot study of self-reported drug use and hair analysis in an arrestee sample." Mieczkowski uses limited data from the Arrestee Drug Abuse Monitoring (ADAM) program for his article, yet he admits that his study is speculative and designed to stimulate thinking about the possible utility of hair assays. However insufficient his quantitative data, Mieczkowski (2002) best describes the conceptual basis of hair analysis. He describes it as a process where drugs and metabolites that are introduced into the body, circulate in the blood and are then carried to the hair follicle. Once the drugs and metabolites reach the follicle, they are absorbed into the hair shaft and are consequently embedded in the hair shaft protein. As the hair emerges above the scalp, at a rate of about 1.3cm per month, the hair protein retains drugs and drug metabolites. Therefore, he suggests, recent use (24-129 hours after intake) is best determined by use of a urinalysis.(p. 99)

Kintz and Samyn (1999) studied the effectiveness of testing hair for amphetamines, including ecstasy. Kintz and Samyn state that ecstasy use "has become a widespread habit of young people at techno and rave parties. The popularity of ecstasy has greatly increased and it is assumed that the number of people having used such compounds has tripled in the last five years."(p. 143) Kintz and Samyn also note that there are relatively few studies done on the analysis of ecstasy in hair specimens. In fact, Kintz and Samyn calculate that between 1980 and 1998, only ten references for hair analysis of ecstasy was found in international literature and meeting presentations.(Kintz and Samyn, 1999, p. 143) Methylenedioxymethamphetamine (MDMA), is the scientific name for the chemical compound that composes ecstasy and is found in specimen samples; MDMA is commonly used to name ecstasy in literature. Whereas MDMA can be found in a urine sample only one three days after ingestion, hair analysis can detect the presence of MDMA months after ingestion.(Kintz, Cirimele, Tracqui, & Mangin, 1995, p. 162) Kintz et al (1995) state that the use of GC/MS to detect amphetamines (AP), methamphetamines (MA), methlylenedioxyamphetamine (MDA), and MDMA is "highly specific, sensitive and precise" and that "analysis for the presence of stimulants in hair is a valid means of determining stimulant use history."(p. 166)

Borack's (1997) study suggests that the sensitivity of a test, or the probability of detecting drug use, "can greatly impact the effectiveness of a urinalysis program"(p. viii)

and "exerts a profound impact on deterrence."(p. 10) The relationship that is hypothesized in this thesis is that increased *detection probabilities* of the Marine Corps' drug detection program will result in increased effectiveness. This thesis examines whether hair testing is an effective means of detecting illicit drug use, primarily by comparing urinalysis results and hair test results. The hypothesized relationship will be examined to answer whether the hair test will be effective in detecting drug users, and if so, by what magnitude when compared to the urinalysis. Borack's examination of sensitivity enhancements will provide a foundation on which to generate an estimate of the probability of detecting drug use during a given period when using a hair test. Borack's (1997) study will also be used to examine the complicated relationship of detection and deterrence.

The objective of the Marine Corps' urinalysis program is to detect and deter drug use among Marines. Marines who are successfully deterred from using drugs afford the Marine Corps increased readiness, health, and safety. Furthermore, deterred users do not contribute to the cost of degraded productivity in the workplace. If deterrence is dramatically increased, drug use would wane and detection levels would subsequently decrease. The true measure of effectiveness of a drug-testing program then, is the *degree at which the program deters drug use by people who would otherwise use drugs if no testing program were implemented.* Detection percentages alone cannot determine the effectiveness of a drug-testing program, and only have meaning if compared to *actual* use percentages and deterrence factors. In short, low detection percentages can indicate either a testing procedure that ineffectively identifies drug users *or* an effective testing procedure that deters a vast number of potential users.

C. REVIEW OF STUDIES COMPARING URINALYSIS AND HAIR TEST EFFECTIVENESS

The effectiveness of hair tests is best captured when the magnitude of proportional differences can be compared to the effectiveness of urinalysis. Several studies have been done that compare the two methods; it is these studies that offer the best perspective of hair analysis and will be the foundation of comparative figures throughout this study. Whereas the effectiveness of the urinalysis is based upon the

comparison of self-reported drug use with urinalysis results, the effectiveness of the hair test in the following studies is based upon the comparison of self-reported drug use *and* urinalysis results with hair test results. Some studies (Cook, Bernstein, Arrington, Andrews, & Marshall, 1995) question the validity and accuracy of self reporting, estimating that self-reported drug use falls far short of actual use. Many of the following studies also use populations of known drug users and drug addicts as the population being studied, as there are undoubtedly drugs in the biologic systems of the population.

Kintz (1996) suggests that hair testing is 35% more effective at detecting drugs than urine testing and is especially more effective at detecting cocaine use. Kintz's (1996) study used a population of 100 known drug users from a detoxification center and tested for cocaine, opiates, stimulants, and marijuana. Kintz (1996) found that whereas the metabolites of drugs are most often found in urine samples, the parent drugs are most often detected in hair samples. However, the most significant finding was that for the purposes of monitoring drug use history, the hair analysis far surpasses the urinalysis in creating an accurate picture of the frequency of drug intake. Kintz (1996) suggests, "The success of urine drug testing of drug abusers is dependent on the frequency of testing. Most drugs of abuse are detected in urine for 2 to 3 days after a single drug exposure. Therefore, to be effective, two urine tests have to be performed each week. It has been shown that random rather than regular and predictable sampling gives higher detection rates."(p. 454) Another drawback of the urinalysis is that it cannot determine whether the low presence of a drug in urine indicates that the subject used small amounts or whether he or she abstained from drug use 2 or 3 days before being tested.(Kintz, 1996) On the other hand, Kintz (1996) found that "The possibility of distinguishing between heavy, medium, light, or no drug use by retrospective hair analysis and the potential of linking such findings to other factors was proposed as a promising approach for referring individuals to appropriate supervision programs."(p. 454) These findings by Kintz, which are supported by other studies such as Tagliaro et al (1997), Mieczkowski (1998), and Feucht and Stevens (1994), are significant to this study because they provide the basis for examining the validity of the urinalysis while offering an effective remedy.

As was mentioned above, the level of effectiveness of a urinalysis is gauged by the magnitude of self-reported drug use rates. Mieczkowski (1998) conducted a study

that examined the relationship of self-reporting, urinalysis, and hair testing with a population of youthful juvenile offenders. Mieczkowski states, "Urine-based testing consistently shows that there is more drug use than is revealed by interviewing, and consequently it suggests that prevalence estimations based on surveys alone are under-reports of the true incidence of use. An interesting question is how these data might change if a *different* bioassay technology were used which extended the window of retrospective observation?"(Mieczkowski, 1998, p. 1549) Mieczkowski presents facts that highlight the difference of self-reporting, urinalysis, and hair analysis. For instance, in a drug use interview of juvenile offenders, 6 of 88 admitted to *ever* having used cocaine (7.4%), urinalysis revealed that 7 of the 88 (8%) had used cocaine, and hair analysis revealed that 50 of the 88 (56.8%) had used cocaine in the last two months.(Mieczkowski, 1998, p. 1551) Mieczowski quotes another referenced author in this study, Thomas Feucht, as saying, "'If urinalysis results are used to demonstrate the level of need (or lack of need) of drug education, intervention, or treatment among juvenile arrestees/detainees, the urinalysis data vastly underestimate the scope of the population at risk.'"(Mieczkowski, 1998, p. 1551)

Cook et al (1995) conducted a thorough study that investigated the relationship of self-report, urinalysis, and hair analysis in the workplace. The significance of their study is that their population consisted of a large number of typical American citizens between the ages of 18 and 54 versus a population of known drug addicts or arrestees. The population studied by Cook is very similar to the population of the Marine Corps and provides a suitable representative population for comparisons made with the Marine Corps. Cook et al's population was chosen from a steel plant "mainly because its work force was sufficiently large and varied but with a considerable proportion of young, blue-collar males, among whom the use of alcohol and illicit drugs is especially concentrated."(Cook et al, 1995, p. 406) Participation in Cook's study was rewarded with payment of $20 and eligibility in a raffle cash prize of $1,000. Participants were given a code number and all responses were both anonymous and confidential. The purpose of Cook et al's (1995) thorough research was to examine whether self-report drug use data was valid, whether hair test and/or urinalysis results sufficiently determine actual drug use rates, and the best method of assessing actual drug use rates.

Cook et al's (1995) unique study is extremely valuable for this study because of the similarities of population, self-report methods, drugs tested, and methods of testing used. Cook et al indirectly question the validity of the data currently used by the Navy and Marine Corps to determine the prevalence of drug use among prospective recruits and the effectiveness of the Navy/Marine Corps urinalysis programs. The National Household Survey, widely used in studies as the basis of drug prevalence among Americans, is solely a self-report survey that provides erroneous data according to Cook et al. In fact, Cook et al (1995, p. 420) suggest, "The drug use prevalence rate in a workplace is likely to be approximately 50% higher than the estimate based on self-reports." Cook et al's study concludes, "When the urinalysis and hair analysis results are combined with self-report, the resultant prevalence rate (14.2%) was 51% higher than the rate based on self-report alone."(Cook et al, 1995, p. 423)

Feucht and Stevens (1994) conducted the same study as Mieczkowski (1998)on the same population of juveniles mentioned above. Both Mieczkowski and Feucht and Stevens had the same findings in their studies, to include under-reporting and comparative results of urine and hair testing. Feucht and Stevens (1994) suggest that the implementation of hair analysis in testing for marijuana use is not as effective as the urinalysis. Feucht and Stevens spoke with the director of Psychemedics Corporation, a popular hair-testing lab, about the reason for hair test limitations in detecting marijuana use. The director, Dr. Werner Baumgartner, stated that the low concentration of marijuana metabolites in the hair "Poses formidable analytical problems and has the result of rendering marijuana screening assay of hair somewhat less effective" than cocaine, PCP, and amphetamines.(Feucht and Stevens, 1994, p. 105) Dr Baumgartner also adds that, "The urine test for marijuana is contrastingly the most effective of the urine assays because of the relatively slow excretion of marijuana metabolites" from the body.(p. 105) Feucht and Stevens' (1994) research corroborates Spiehler (2000), Tagliaro et al (1997), and Mieczkowski and Newel's (1993) findings that the hair analysis is better at detecting the use of cocaine, opiates, and amphetamines, whereas the urinalysis is better at detecting marijuana use.

Italian researchers have determined that for the purposes of ascertaining a thorough drug use history among driving license applicants, hair tests combined with

urinalysis offer the best results. Montagna, Stramesi, Groppi, and Polettini (2000) conducted a simultaneous urine and hair testing study using a population of 214 driving license applicants. Their research suggests "Owing to its ability to accumulate drugs which, by converse, quickly disappear from biological fluids, hair is the matrix of choice for the assessment of past exposure to drugs, in terms of weeks to months preceding hair collection. Therefore, hair analysis provides complementary information to urinalysis, which on the contrary informs on recent or current exposure."(Montagna et al, 2000, p. 158) Since hair grows approximately 1.3 cm per month, a hair test cannot detect drug ingestion until the hair grows sufficiently before cutting. A urinalysis, however, can detect drug intake within hours of ingestion. The windows of detection complement each other in that one shows recent exposure, whereas the other shows long-term exposure.

Psychemedics Corporation provides data that suggests hair testing is substantially more effective in identifying drug use for all drugs, including marijuana. Psychemedics provides two studies, the National Institute of Justice Field Study and the Steelcase Study, that illustrate their claim. The National Institute of Justice Field Study conducted a radioimmunoassy (RIA) of hair to determine the presence of cocaine, PCP, and opiates in over 200 parolees. The findings are listed in Tables 2 and 3.

Table 2. Positive Urine and Hair Comparison: Initial Screening

Drug type	Percent Increase in Detection with Hair
Cocaine	420%
PCP	270%
Opiates	180%

(Pyschemedics Corporation, 2003)

Table 3. Positive Urine and Hair Comparison: One Year Surveillance

Drug type	Percent Increase in Detection with Hair
Cocaine	430%
PCP	500%
Opiates	50%

(Psychemedics Corporation, 2003)

The results above are for RIA of hair only and are not specifically listed as being confirmed by GC/MS testing procedures. RIA, although an effective screening tool, does not alone confirm the presence of illicit drugs and would have to be accompanied by GC/MS tests to determine specific types and amounts, as mentioned above by Cassani et al (1997). The Steelcase Corporation study of 774 job applicants is likewise a comparison of urine and RIA of hair by Psychemedics Corporation labs. The hair test and urinalysis were conducted side by side on each individual. The results of the Steelcase Corporation study are listed in Table 4.

Table 4. Results from Urinalysis vs. Hair Test Comparison (Percentage Positive)

	Urine	Hair
Cocaine	0.5%	8.4%
Marijuana	0.5%	3.5%
Other Drugs	1.7%	6.1%
Overall Positive	2.7%	18.0%

(Psychemedics Corporation, 2003)

Psychemedics does not provide scientific data with their advertised studies and bias based upon financial reward should be considered when viewing the results listed in Tables 2, 3, and 4. Studies about the effectiveness of hair testing in regard to marijuana raise doubt to the results listed in Table 4, where hair testing appears to be much more effective than urine in detecting marijuana use. Dr. Baumgartner, director of Psychemedics, contradicts the findings for marijuana when he responds to Feucht and Stevens (1994) above, stating that, "The urine test for marijuana is contrastingly the most effective of the urine assays."(p. 105)

The studies highlighted above bring to light several key aspects of the drug testing program. First, the studies will generate an estimate of actual drug users in the Marine Corps, considering drug detection percentages and self-reported use percentages.

Second, these studies will offer perspective on the magnitude of proportional differences between the urinalysis detection levels and hair test detection levels. With proportional differences in detection estimated for hair test implementation, further investigation can be done on the deterrent effects of hair testing.

D. ANALYSIS OF HAIR TEST AND URINALYSIS DETECTION EFFECTIVENESS

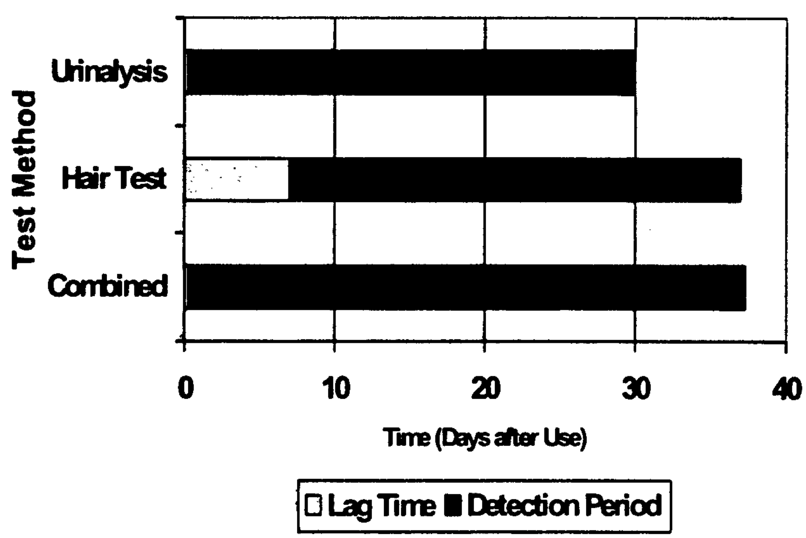
Controlled scientific studies have shown that hair testing is more effective than the urinalysis for the detection of cocaine, amphetamines, and opiates.(Kelly et al, 2000) This fact is clearly related to the hair test's ability to reach significantly farther back into the history of the subjects. Cocaine, amphetamines (including ecstasy), and opiates can be accurately detected for one month, given a short 1.3 cm segment of hair. Borack (1997) notes that increasing the sensitivity of the urinalysis from 2 days to 4 days had a "profound" impact on deterrence. Increasing sensitivity, or the probability of positively detecting illicit drug use, from 3 days to 30 days after ingestion would have even a more profound impact; this increase in sensitivity is well within reason with the hair test. One drawback of the hair test, however, is that it does not sufficiently detect current or near-term drug use (within one week) because the hair that contains evidence of drug use has not grown sufficiently long enough above the scalp. Using scientific studies that compare urinalyses and hair test results for certain drugs, to include marijuana; an estimated range in drug detection probability percentages for the hair test will be developed and compared to urinalysis detection probability percentages.

Controlled scientific studies (Tagliaro et al, 1997) have shown that the urinalysis sufficiently detects marijuana use since the metabolites of marijuana linger in a subject's body for about one month. Hair testing provides no real advantage over the urinalysis in detecting drug use within one month of ingestion. In fact, the hair testing method is disadvantaged, relative to the urinalysis, because the hair sample must grow approximately one week after drug ingestion before the hair is sufficiently long enough to be tested.

1. Comparison of Windows of Detection

The window of detection is the period during which a hair or urine specimen is likely to carry a drug or drug metabolite that can be reasonably detected by a drug test. The urinalysis windows of detection for various drugs are different because of the variation in duration that different chemicals fully metabolize in the body. On the other hand, the hair test windows of detection for drugs are relatively consistent because the drug and drug metabolites do not dissipate in the hair shaft protein. The following figures illustrate the comparative windows of detection for marijuana, cocaine, and amphetamines such as ecstasy. The hair test window of detection is illustrated for a 1.3cm segment of hair, taken at the root; this corresponds to approximately one-month of growth. The lag time is the period immediately after drug ingestion when sufficient quantities of the drug cannot be detected in the specimen being tested. The lag time for a urinalysis is several hours, whereas the lag time for a hair test is approximately one week. Figures 1 and 2 represent detection periods for hair and urine specimens taken at the same time.

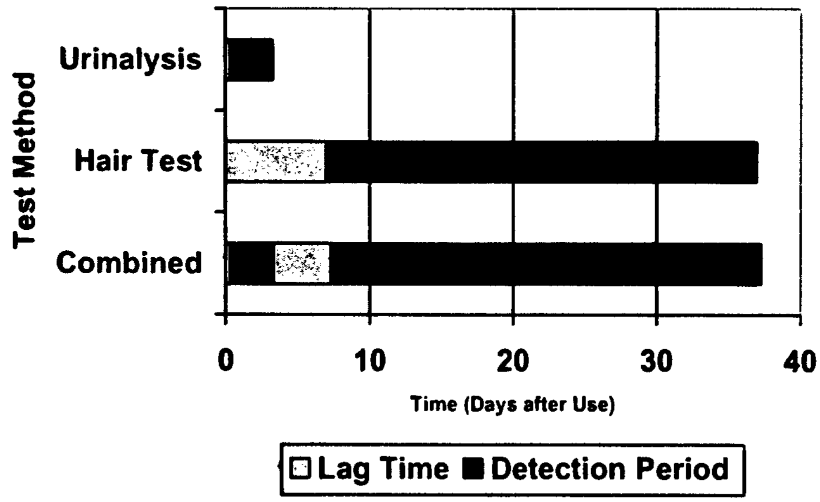
Figure 1. Window of Detection (Marijuana)



Note that in Figure 1, the combined window of detection for the urinalysis and hair test covers the greatest period. It is also important to note that the detection window of a hair test, when not used with a urinalysis, does not offer any great advantage over the urinalysis. Only when a segment of hair exceeds 1.3cm in length, will the long-term detection properties of the hair test be realized when testing for marijuana. Detection periods aside, the effectiveness of the hair test in detecting marijuana use is not as assured as the urinalysis method. Tagliaro et al (1997) suggest, "The very low concentrations [of cannabinoids] present in the hair hamper the development of simple, routine analytical methods and lead to the risk of misinterpretation of results." (p. 135) The detection window and accuracy of the hair test for marijuana do not reasonably justify using a hair test for the purpose of increasing detection probabilities. Taliaro et al (1997), Spiehler (2000), Feucht and Stevens (1994), and Mieczkowski and Newel (1993) support the relative advantage of the urinalysis in detecting marijuana use.

The windows of detection for illicit drugs such as cocaine, amphetamines, methamphetamines, and ecstasy (methylenedioxymethamphetamine) are displayed in Figure 2, below. The windows of detection for the urinalysis and the hair test are significantly different and contrasting. The urinalysis window of detection covers a period of detection of about three days, beginning hours after ingestion. The hair test period of detection covers a period of 30 days (using a 1.3cm length of hair), beginning approximately seven days after ingestion. The combined effect of the hair test and urinalysis covers a period of approximately thirty-seven days, with a low probability of detection period from three to seven days after ingestion. The wide window of detection offered by a combined urinalysis/hair test—and even the hair test alone, precludes a drug user from effectively gaming a drug test by abstaining from drug use just days prior to an expected test.

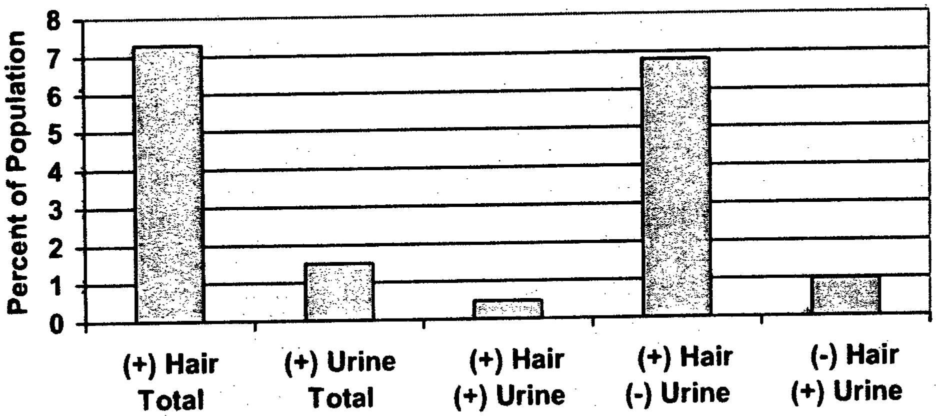
Figure 2. Window of Detection (Cocaine and Amphetamines)



2. Comparison of Urinalysis and Hair Test Sensitivities

The effectiveness of the hair test relative to the urinalysis in detecting opiates and cocaine are represented in Figures 3 and 4. It is important to note the similar results illustrated in the figures that represent two different drug types. Both drug types illustrated in Figures 3 and 4, cocaine and opiates, are drug types that the Navy drug detection labs identifies in their urinalysis tests.(Past, 1999) Detection percentages of the hair test for opiates and cocaine far exceed the detection percentages of the urinalyses taken on the same day from the same subjects. It is likewise important to note the complementary properties of the hair test and urinalysis. This is evidenced by the small percentage of positive samples found in *both* hair and urine for opiates and cocaine. The percentage of personnel detected for drug use, as reflected in Figures 3 and 4, corresponds to the contrasting magnitudes and complementary nature of the windows of detection, as illustrated in Figure 2. These results suggest that using a hair test and a urinalysis in tandem would be the optimal method of detecting both near-term and long-term drug use.

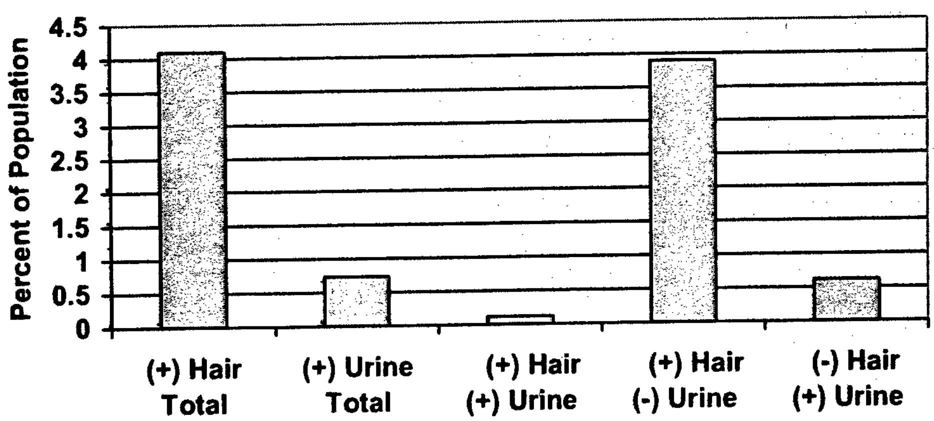
Figure 3. Comparison of Positive Cases (Opiates)



Note: Figures represent simultaneous urine and hair specimens taken to detect Opiate use among a population of 812 recovering Italian drug addicts who were applying to receive a driving license. 91.7% tested negative on both specimens.

Adapted from "Integrated use of hair analysis to investigate the physical fitness to obtain the driving licence: a casework study" by F. Tagliaro, Z. De Battisti, G. Lubli, C. Neri, G. Manetto, M. Marigo, 1997, Forensic Science International, 84, p. 134. Copyright 1997 by Elsevier Science Ireland Ltd.

Figure 4. Comparison of Positive Cases (Cocaine)



Note: Figures represent simultaneous urine and hair specimens taken to detect Cocaine use among a population of 812 recovering Italian drug addicts who were applying to receive a driving license. 95.3% tested negative on both specimens.

Adapted from "Integrated use of hair analysis to investigate the physical fitness to obtain the driving licence: a casework study" by F. Tagliaro, Z. De Battisti, G. Lubli, C. Neri, G. Manetto, M. Marigo, 1997, Forensic Science International, 84, p. 134. Copyright 1997 by Elsevier Science Ireland Ltd.

Borack (1997) concluded that increasing sensitivity of the urinalysis has a profound impact on the probability of detection. Table 5 illustrates the effect of doubling the 100% probability of detection window. Borack (1997) found that "Drug tests which double the period of detection not only increase the probability of detection of a typical drug user by approximately one-third, but also deter an additional 9 percent of drug users" if tested at a typical monthly test rate.(p. viii) The hair test period of detection exceeds the urinalysis period of detection by a magnitude of ten for amphetamines, opiates, and cocaine. The probability of detecting a typical amphetamine, opiate, or cocaine user with a hair test would therefore well exceed the increased sensitivity results proposed by Borack (1997). The hair test and urinalysis detection period parity, when testing for marijuana use, will not generate the increased sensitivity benefits proposed by Borack (1997). Considering the increased probability of detecting a wide variety of illicit drugs with the hair test and the inability of drug users to effectively game a hair test, a profound increase in the in the probability of detecting illicit drug users is expected. If the hair test is used for the detection of all illicit drug use by Marines, to include marijuana use, the magnitude of the increase in probability of detection would likely meet or exceed the 33% increase suggested by Borack (1997). Kintz (1996), who suggests hair testing is 35% more effective than the urinalysis in detecting illicit drug use, supports a 33% increase in detection effectiveness.

Table 5. Impact of Monthly Test Rate and Test Sensitivity on Detection

Monthly Test Rate	Probability of Detection	Increased Sensitivity Probability of Detection
0.00	0.0000	0.0000
0.05	0.0123	0.0167
0.10	0.0242	0.0329
0.15	0.0360	0.0488
0.20	0.0474	0.0642
0.25	0.0587	0.0793
0.30	0.0697	0.0940
0.40	0.0910	0.1224

Adapted from "A technique for Estimating the Impact of Improvements in Drug Testing Sensitivity on Detection and Deterrence of Illicit Drug Use by Navy Personnel" by J. Borack, 1997, Navy Personnel Research and Development Center, San Diego, California, p. 9.

3. The Impact of Gaming on Urinalysis and Hair Test Effectiveness

Gaming is a subject's active behavior that is intended to result in a negative drug test outcome, when the absence of that behavior would likely result in a positive outcome. The urinalysis has been the method of detecting illicit drug use for 22 years; persons subject to the test have subsequently become familiar with the strengths and weaknesses of the urinalysis program. The internet readily provides information and gaming products to the public. Table 6, below, illustrates a small sample of gaming information and products that can be found within minutes on the internet.

The primary methods of gaming a urinalysis are listed below:

1. Timing abstinence to coincide with an upcoming drug test
2. Dilution of urine by drinking large amounts of water prior to the urinalysis
3. Masking the presence drugs/metabolites through the use of "cleansers"
4. Substitution of urine

The urinalysis is especially susceptible to gaming by timing abstinence several days prior to when one expects a urinalysis to occur (i.e. a urinalysis on the day after a weekend or holiday). The urinalysis can only detect cocaine and ecstasy use for three days after ingestion; this poses significant problems in identifying drug use during leave, drug use during federal holidays, and accurate recruit drug use history.

Timing abstinence of drug use prior to a hair test is considerably more difficult for a gamer than it would be for a urinalysis. Assuming a 1.3 cm hair sample is taken from the subject, a corresponding 1-month detection period for illicit drug use will be achieved. Using cocaine, amphetamines, or ecstasy on the first day of a three-day holiday is an effective option for a Marine who wishes to ingest a drug, knowing that the urinalysis cannot detect his/her use when he/she returns to work; this would no longer be an option with the hair test. Substitution, dilution, and cleansing also have considerably less plausibility with hair testing. Although products available on the internet advertise

cleansing shampoos that are designed to clean drugs/metabolites from the hair, researchers have not found any evidence that shampoos significantly impact the detection

Table 6. Gaming Products Found on the Internet

Website	Product	Product Description
www.cleartest.com/	Kits, information,urine	"ClearTest has drug testing solutions and information to help you pass a drug test! Protect yourself from urine and hair drug tests. We carry urine additives, substitutions (concentrated urine), and detox formulas to pass urine tests"
www.passyourdrug test.com/	Kits, cleansers	"Our master herbalists…go out of their way to stay on top of current testing methods and develop kits to ensure a passing test result"
www.clearchoiceof ny.com/	Products, information, drug testing kits	"One stop shopping for all of your detoxifying needs."
www.pass-any-drug-test.com/	Products, information, drug testing kits	"Are you subject to random drug testing, an athlete, starting a new job, or on parole? Here at Pass-Any-Drug-Test it's one stop shopping for all of your detoxifying needs. We have all of the products you need to pass a urine or hair drug test. We even sell drug tests so you can test yourself for as little as $7.95 each"
http://ipassedmydrug test.com/	Kits, various products	"We offer both same day and permanent detoxification programs that have been tested over time since 1993 with proven results to remove all drug metabolites and unwanted toxins from your system"
www.bdtzone.com/ home.asp	Powdered urine, additives, kits, cleansers	"We realize how important it is for you to pass a drug test. To help you in this endeavor, we've acquired the best anti-drug testing products on the market, gathered the information you need in one place, and made it readily accessible"
www.testclear.com/	Powdered urine, cleansers, shampoo	"The Powdered Urine Kit is perfect for job tests. Clear Choice Shampoo is for the hair test. Drinks are used only for supervised tests"
www.thewhizzinator .com/	Urinating device	"The **WHIZZINATOR**© is an easy to conceal, easy to use urinating device with a very realistic prosthetic penis. It has been extensively tested and proven to work under real-life conditions"

Note: Key words "drug test" were used on web browser. Google, to find the websites listed in this figure (Nov, 2002)

of drugs/metabolites.(Segura, Stramesi, Redon, Ventura, Sanchez, Gonzalez, San, & Montagna, 1999) In fact, laboratories go to great lengths to cleanse the hair themselves in order to ensure passive exposure to smoke or drug residues does not result in a false positive. Examination of gaming for both the urinalysis and hair test provides insight into the overall effectiveness of both methods. *If gaming a drug test results in a decrease in the probability of being detected, the detection and deterrent properties of that test would be adversely affected.* It is hypothesized that gaming has less impact on the results of the hair test than it does on the results of the urinalysis.

E. EXAMINATION OF HAIR TEST RACIAL BIAS

Racial differences in the color, texture, and drug bonding properties of hair have led to concern and controversy that a hair test would be biased toward certain races. Whereas there is no scientific study that suggests a hair analysis is race biased, a number of scientific studies exist which suggest a hair analysis is not race biased. Dr. Benjamin Hoffman conducted a study titled, "Analysis of Race effects on Drug Test Results." In this study, he compared the results of urinalysis and hair analysis from a population of 1,852 police department candidates who considered themselves either black or white from the four options: black, white, Hispanic, other. The subjects consented to both a urinalysis and a hair analysis.(Hoffman, 1999, p. 613) Hoffman concluded that, "There was no evidence that one group was more adversely affected by hair testing, compared with urine testing."(Hoffman, 1999) He also adds, "The nature of the hypothesized bias is not clear; however, true variation in rates of drug use among particular subgroups classified by race, accurately revealed by hair tests, might be considered 'bias' by some observers."(Hoffman, 1999, p. 612)

Kelly, Mieczkowski, Sweeney, and Bourland (2000) conducted a thorough study, similar to Hoffman, but used hair color and/or race as the independent variable, whereas Hoffman only used black or white race. Kelly et al (2000) examined whether hair test and urinalysis results have a relationship with hair color, whether urinalysis results have a relationship with race, and whether the distributions of both hair test and urinalysis results are consistent across drugs or with generally documented ethnic or racial drug use

prevalence rates. The method and population used in their study is significantly thorough and comprehensive, described as follows. First, hair was collected from 2,000 random samples and categorized by forensic anthropologists according to seven visual color categories. Then hair samples were tested for marijuana, cocaine and amphetamines using RIA screening and GC/MS confirmation. The distribution of positive and negative hair samples for each hair color category was compared. Urine specimens were collected from 4,000 subjects and were tested for marijuana, cocaine, and amphetamines. After the urinalysis, forensic anthropologists categorized urine donors as black, Caucasian, Hispanic, Asian Pacific Islander, or other according to photographs of the subjects. Additionally, hair color of urine donors was also determined and categorized according to one of seven hair colors. The distribution of positive and negative urine samples for each race and hair color was then compared.(Kelly et al, 2000)

The use of a large and varied population combined with the variety of drugs assayed gives great credibility to the results of Kelly et al. All results of the studies Kelly et al (2000) conducted reached the conclusion that neither race nor hair color is a factor in the outcome of a hair analysis. They summarize their findings by stating, "There is no compelling or consistent pattern of assay outcomes that lead us to conclude there is a racial bias associated with hair analysis."(Kelly et al, 2000, p. 83) Interestingly, they found that while cocaine use detection rates were higher among African-Americans, amphetamine use detection rates were lower.

Several non-scientific essays have elaborated on the controversy surrounding race and the hair analysis. Tom Mieczkowski quotes two scientists, Osborne and Feit who stated in 1992, "'when race is used as a variable in research there is a tendency to assume that the results obtained are a manifestation of the biology of racial differences...researchers, without saying so, lead readers to assume that certain racial groups have a special predisposition, risk, or susceptibility' to the problem studied."(Mieczkowski, 1999, p. 5) Mieczkowski also concludes that, "The unreflective and unspecified use of racial and ethnic categorizations in the case of interpretation of hair analyses serves as a further example of the 'badly muddled' method of data analysis and interpretation which permeates this literature."(Mieczkowski 1999, p. 5) Similarly, Mieczkowski (1999) states, "The allegation of 'racial bias' for a bioassay is intrinsically a

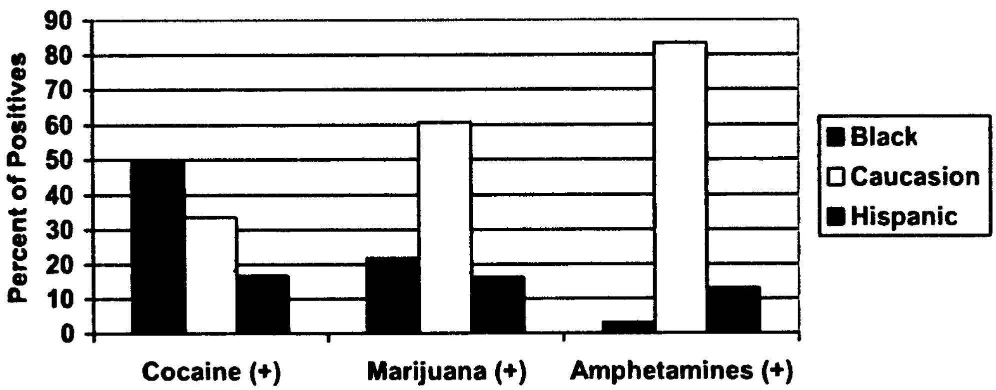
sensational and attention-grabbing one. Often embedded in such an allegation are all manner of hidden assumptions, implied differences, and 'appeals to common sense' and social stereotypes which are relied upon to lend social meaning to the concept of race."(p. 18)

Kidwell (1990) and Holden (1990) assert that the hair test is race biased because drugs and drug metabolites bind to thick, black hair while they do not bind to thin, blonde hair. The results of Kelly et al (2000) illustrate that the urinalysis results of a random population of 2,000 subjects reflect the same proportion of drug use detection among races that the hair test does. They conclude that the hair test is not race biased, but identifies drug use preferences among different races.(Kelly et al, 2000) To illustrate this point, Figure 5 displays the results of a urinalysis that tested for amphetamines, cocaine, and marijuana. The percentage of black subjects was 16.7%; Caucasian subjects 60.25%, and Hispanics 20%. The remaining 3.05% of the population consisted of Asian Pacific or other races; these races are not illustrated in Figure 5. A dramatic over-representation of black subjects was positive for cocaine on the urinalysis, accounting for 50% of the positives. Caucasians were over-represented in amphetamine use, accounting for 83.3% of the positives.

Figure 6 illustrates results Kelly et al (2000) established by taking hair samples of 2,000 random subjects, classifying them by one of seven hair colors as determined by a forensic anthropologist. Black hair is dramatically over-represented for cocaine use, but highly under-represented for both marijuana and amphetamine use. Dark brown hair is the only hair color over-represented, though not dramatically, for each of the three drug types. Dark brown, medium brown, light brown, and blond hair—typically associated with Caucasians—comprises an over-representative majority of amphetamine positives. The results of the hair test correspond with the results of the urinalysis. *Due to the dramatic increase in the sensitivity of a hair test when testing for cocaine and amphetamines, the dramatic differences in drug preference among different races and among people with different hair color will be profoundly accentuated.* The dramatic increase in sensitivity of the hair test for certain drugs is at the center of the controversy surrounding perceived bias of the test. Although the urinalysis identifies the same proportions of races detected for use of various illicit drugs as the hair test, the magnitude

of all races detected by the hair test is significantly greater. When comparing the magnitude of a specific race detected by the hair test and the urinalysis, it may appear that the hair test is race biased. However, when comparing the proportion of a specific race detected by the hair test and urinalysis, it can be concluded that the hair test is not race biased.

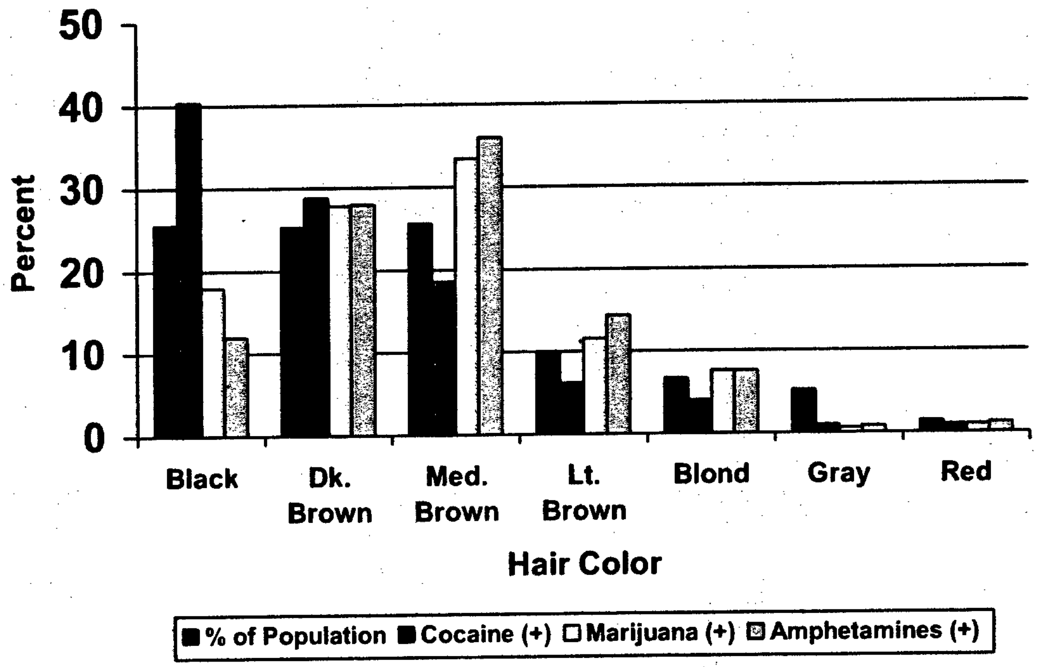
Figure 5. Positive URINALYSIS Result Differences Among Races



Notes: Values represent percentage of race comprising total positives
Percentage of race comprising population of 2.000:
Black: 16.7%
Caucasian: 60.25%
Hispanic: 20%
Total cocaine positives = 77
Total marijuana positives = 378
Total amphetamine positives =168

Adapted from "Hair analysis for drugs of abuse. Hair color and race differentials or systemtic differences in drug preferences?" by R. Kelly, T. Mieczkowski, S. Sweeney, and J. Bourland, 2000, Forensic Science International, 107, p. 74. Copyright 2000 by Elsevier Science Ireland Ltd.

Figure 6. Outcomes of HAIR TEST by Hair Color



Adapted from "Hair analysis for drugs of abuse. Hair color and race differentials or systemtic differences in drug preferences?" by R. Kelly, T. Mieczkowski, S. Sweeney, and J. Bourland, 2000, Forensic Science International, 107, p. 77. Copyright 2000 by Elsevier Science Ireland Ltd.

Analysis of the studies reviewed and analyzed in this chapter suggests that the hair test can be effectively and fairly used by the Marine Corps to detect illicit drug use among Marines. Hair testing effectiveness for most illicit drugs appears to be far superior to the urinalysis. However, analysis of studies that compared the relative effectiveness of the urinalysis and hair test on marijuana detection does not provide conclusive results on which test is better and suggests that there exists a relative parity in detection effectiveness. However, if limitations do exist with the hair test, those limitations may be offset by the vast differences in gaming effectiveness on the urinalysis and hair test. The hair test does not appear as vulnerable as the urinalysis in gaming techniques that can effectively alter the result of a drug test. The hair test appears to detect a large proportion of the black population for cocaine use and may appear to some as being race biased; however, the urinalysis appears to detect a similar proportion of black cocaine users in a given population. The similarity in the proportion of different

races detected for different drugs by both the urinalysis and the hair test elicits great doubt on the bias of the hair test toward or against any race.

IV. HAIR TESTING DETERRENT EFFECTS

The following chapter will review and analyze studies on the deterrent effects of the hair test and urinalysis to determine whether the hair test will effectively deter illicit drug use by Marines. Studies will be reviewed to generate a comparative level of deterrence between the urinalysis and hair test; the comparison will be used in Chapter IV to determine the impact of changes in deterrence on costs and benefits. Additionally, the magnitude of under-reporting that occurs on self-reported drug use surveys will be investigated to determine the relationship of under-reporting, actual use, and deterrence. Under reporting will be factored in the cost and benefit analysis in Chapter V.

A. REVIEW OF STUDIES ON THE DETERRENT EFFECTS OF THE URINALYSIS AND HAIR TEST

Studies suggest that the presence of a drug testing policy is a deterrent to using illicit drugs.(Martinez, 1998) Studies have also suggested that a more robust testing policy, consisting of a test with greater sensitivity or more frequent testing, leads to even greater deterrence.(Borack, 1997; Martinez, 1998) The most frequently used independent variable in studies that measure the strength of a urinalysis program is the frequency of the urinalyses conducted during a given period. An example of this is best illustrated by Martinez (1998), where he compared the urinalysis programs of Army, Air Force, and Navy/Marine Corps and concluded that the service with the most robust urinalysis program had the highest deterrence effect. The relationship between detection and deterrence is of great importance when considering the dramatically increased detection level of hair tests relative to the urinalysis for a wide variety of illicit drugs. Borack (1997) conducted a study that examined the impact of increased detection probability (defined by Borack as "sensitivity) on deterrence by increasing a 2-day detection window to a 4-day detection window. Borack concluded, "The sensitivity of drug tests strongly affected both the estimated probability of detection and the deterrence effect of testing. Compared to the baseline case, drug tests which double the period of detection not only increase the probability of detection of a typical drug user by approximately 1/3, but also

deter an additional 9 percent of drug users."(Borack, 1997, p. 12) If the detection window is increased from 3 days to 30 days by using the hair test, it is hypothesized that deterrence levels will increase profoundly. Borack's and Martinez's studies will be used to provide an estimated, quantifiable range of the deterrent effect of hair testing and will be compared with the deterrent effect of the urinalysis.

Deterrence is the factor of primary interest for the Marine Corps' drug policies—with a high level of deterrence, there results a low level in drug use. Studies have been conducted that estimate the degree of deterrence of the Navy and Marine Corps drug testing programs and are indicative of the effectiveness of these programs. A thesis conducted by Antonio Martinez (1998) is a comprehensive study of the services' drug policies and the effects on deterrence of each. The thesis, titled, "A Statistical Analysis of the Deterrence Effects of the Military Services' Drug Testing Policies," is a replication of a study conducted by Borack and Mehay (1996), "A conceptual Model for Determining an Optimal Drug Testing Program." Martinez corroborates Borack and Mehay's estimation that drug testing does have a significant deterrent effect on illicit drug use. Martinez's research suggests, "The military services' drug testing policies have a significant impact in deterring illicit drug use when compared to a representative portion of the civilian population not subject to testing."(Martinez, 1998, p. 71) Whereas Borack and Mehay studied only the relationship of deterrence to the Navy's drug testing policy, Martinez studied the relationship of deterrence to the policies of all military services. This gave him the opportunity to compare deterrence levels of the services, based upon the strictness of their drug testing policies. He then concluded that the "Deterrence effect is influenced by the strictness of the drug policies. That is, service programs that test their personnel for illicit drugs with a greater intensity and frequency than their sister services tend to enjoy a higher deterrence rate."(Martinez, 1998, p.71)

Martinez also identifies a follow-on study conducted by Borack (1997) that investigates how increased sensitivity of a urinalysis would effect detection and deterrence. Borack examined the deterrence effect of increasing the time of positive detection from two to four days after illicit drug ingestion. Martinez states, "Borack's hypothesis was rooted in the assumption that the deterrence effect of drug testing was a function of the probability of illicit drug use detection. 'Simply put, the higher the

probability of detection, the greater is the deterrence effect.'"(Martinez, 1998, p. 14) Martinez's examination of Borack's study suggests, "Improvements in drug testing sensitivity would have a significant impact upon testing rates for specific deterrence and detection levels and on the costs of testing."(Martinez, 1998, p. 15) Furthermore, Martinez highlights Borack's finding by stating, "There are profound tradeoffs between testing sensitivity and testing rate and that improvements in test sensitivity can greatly impact the cost and effectiveness of a drug testing program."(Martinez, 1998, p. 15)

Martinez includes in his study a table that illustrates the deterrence effect of drug testing among the Army, Air Force, and Navy/Marine Corps. His table, shown below, suggests that the Navy/Marine Corps drug testing policies are responsible for deterring 10.59% from using drugs within the last 30 days and 15.53% from using drugs within the past year, when compared to a similar population who was not tested in the civilian sector. All values noted below are significant at a 99 percent level of confidence.

Table 7. Marginal Effects of Drug Testing Deterrence

Independent Variable	Dependent Variable: Use within past 30 days	Use within last year
Army	-9.96%	-13.28%
Navy/Marine Corps	-10.59%	-15.53%
Air Force	-13.52%	-20.51%
Military	-11.17%	-12.26%

Adapted from "A Statistical Analysis of the Deterrence Effects of the Military Services' Drug Testing Policies" by A. Martinez, 1998, Master's Thesis, Naval Postgraduate School, Monterey, California, p. 68.

A significant drawback of Martinez's study is the reliance upon two surveys that rely solely on self-reported drug use. Both the Department of Defense Survey of Health Related Behaviors Among Military Personnel (DODWWS) and the National Household Survey on Drug Abuse (NHSDA) may significantly under-report drug usage at two different degrees. Cook et al (1995), as mentioned above, suggest that surveys can under-report drug use by as much as 51%. Furthermore, military personnel may be much more likely to under-report actual drug use than a comparable civilian population for a variety of reasons. First, servicemen take oaths, sign agreements, and follow strict codes

that clearly mandate behavior—including the explicit demand to avoid drugs. Admitting to breaking an oath, agreement, or code may be significantly more difficult for a service member than a civilian counterpart who would merely admit to violating some widely accepted ethical behavior. Second, servicemen may be very reluctant to admit to having used drugs—even if confidentiality is promised—because of the implications of losing a career and profession. A civilian counterpart, on the other hand, does not necessarily have those grand implications looming and may be more willing to trust in the confidentiality that is promised. While recognizing the significance of under-reporting on self-reported surveys is critical, it is equally essential to recognize the variability in the degree of under-reporting between military personnel and civilians. Perhaps it is the very variability between the self-reporting tendencies of civilians and servicemen that produced the results listed in Table 5. Although Martinez notes the possibility of under-reporting, it has hardly been recognized at the magnitude suggested by Cook et al (1995). Furthermore, the baseline data used in the Borack and Mehay (1996) study that Martinez replicates is derived from a 1991 NHSDA survey.

Richard Diddams (1999) conducted a similar thesis to Martinez, using the same data from both the 1995 DODWWS and 1995 NHSDA. Not surprisingly, Diddams also concluded that, "The DoD's urinalysis program appears to be a major factor in contributing to a deterrence effect among military members."(Diddams, 1999, p. 83) Diddams (1999) came to this conclusion after determining that the independent variable of being a service member had the most impact on the dependent variable, drug deterrence effect during the past 30 days. Other independent variables included gender, children, marital status, race, age, and education.(Diddams, 1999) By using logit estimates, Diddams suggests that "Changing only whether the person is in the military reduces the probability of drug use in the past year by 20 percentage points, representing a reduction of 70 percent. For past month drug use the probability is 14 points lower, a reduction of nearly 80 percent."(Diddams, 1999, p. 49) Similar to Martinez (1998), Diddams (1999) recognizes the possibility of under-reporting on surveys but fails to recognize the magnitude and variability of under-reporting on the surveys that formed the basis of his hypothesis.

B. ANALYSIS OF DETERRENT EFFECTS OF THE URINALYSIS AND HAIR TEST

Drug deterrence offers several benefits for the Marine Corps. Among these benefits are the avoided costs of degraded performance, health problems, safety mishaps, and attrition. The deterrence level of the hair test may be profoundly greater than the urinalysis and can thus have a significant impact on avoided costs. Since no studies have been conducted on the deterrence effect of the hair test, the urinalysis studies highlighted in this thesis will provide the framework on which estimated ranges of hair test deterrence levels will be developed.

1. Analysis of the Relationship Between Self-reported Use, Actual Use, and Deterrence

It is hypothesized that positive urinalysis percentages significantly under-represent actual use percentages and self-reported use percentages likewise significantly under-represent actual use percentages. Most studies assume that self-reported use percentages are approximately equal to actual use percentages. Urinalysis results are compared to self-reported use rates—not *actual* use rates, to measure the effectiveness of the urinalysis. Cook et al's (1995) study on the under-reporting tendencies of a large population of American citizens will be used to base a general estimate of the level of under-reporting that occurs on the DODWWS and NHSDA self-report surveys. Both the DODWWS and NHSDA are widely used by researchers studying the effects of deterrence.(Borack, 1997; Diddams, 1999; Martinez, 1998; McCrea and Hey, 2001) Cook et al, however, do not rely upon the urinalysis alone to corroborate self-reported drug use. Cook et al use both the urinalysis *and* hair test to get a more accurate portrayal of actual use percentages in order to corroborate self-reported drug use percentages. They found that, "Drug use prevalence rate in a workplace is likely to be approximately 50% higher than the estimate based on self-reports."(Cook et al, 1995, p. 420) Based upon Cook et al's research that investigates the validity of hair testing for employees, this study will generate estimates of the percentage of Marines who under-report drug use. Using the McCrea and Hey (2001) study, a range of estimated actual Navy users during 1995 will be generated and compared to both the percentage detected in 1995 and the

percentage who self-reported drug use in 1995. It is hypothesized that *the hair test will increase the detection level percentages to a value that is higher than self-reported use percentages.*

Studies conducted by Cook et al (1995), Feucht and Stevens (1994), Mieczkowski et al (1998), and Mieczkowski and Newel (1993) and have explored the nature of self-reported drug use, relative to the results of hair and urine testing and have concluded that self-reported use does not adequately represent actual use. *Investigating the relationship of self-reported drug use, detection, and actual drug use is important in analyzing the possible deterrent effects of the hair test because, unlike the urinalysis, the hair test has the potential of uncovering a wide disparity between actual use and self-reported use.* Self-reported use, based upon the DODWWS and NHSDA, has been equated with actual drug use in studies (Diddams, 1999; Martinez, 1998; McCrea & Hey, 2001) that have investigated the deterrent effects of the Navy/Marine urinalysis program. Based upon self-reported drug use data, all of these studies have concluded that the Navy/Marine urinalysis program significantly increases drug deterrence. Since these studies compared self-report data from civilians and servicemen alike, it can be reasonably expected that any difference in self-reported drug use between civilians and servicemen can be attributed to the drug-testing program. The magnitude of the *differences* in self-reported use is not in question; however, the magnitude of self-reported use by servicemen and civilians alike is disputable.

Figure 7 represents the model used by Diddams (1999), Martinez (1998), and McCrea & Hey (2001) that equates self-reported drug users and actual drug users. The population represented in the Figures 7, 8, and 9 consists of only those Marines who would be prone to illicit drug use. The models do not include Marines who would avoid drug use, even without a testing program. Note that in Figure 7, self-reported users and actual drug users are portrayed to be the same quantity. In a population prone to illicit drug use, this model suggests that deterred users are those who do not self-report drug use and those who are not identified users. The number of deterred users is therefore greatly inflated, as the number of non-reported drug users is proportionally greatly underestimated. Figure 8 illustrates a model that accounts for the under-represented population of drug users, thereby reclassifying all of the unidentified drug users

(unidentified by either urinalysis or self-report) from deterred users to non-deterred users. It is hypothesized that the urinalysis currently only identifies a small fraction of actual users and a larger fraction of the self-reported users.

Figure 7. Population of Marines Prone to Illicit Drug Use (Current Assumptions) Urinalysis Model

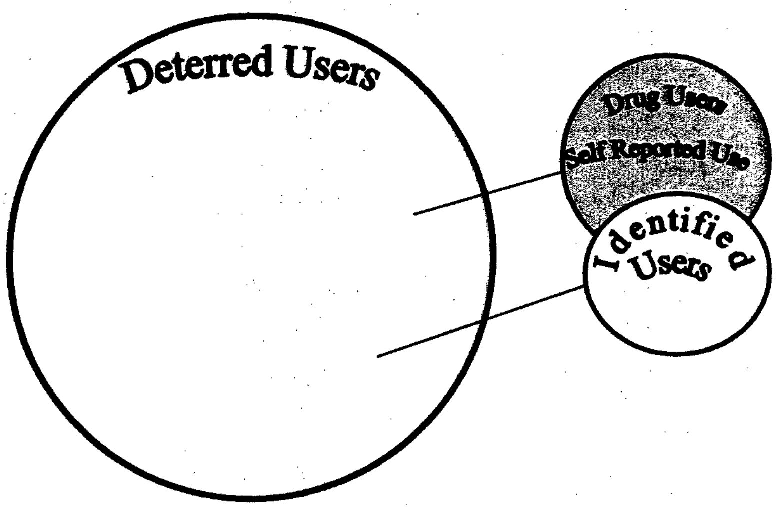
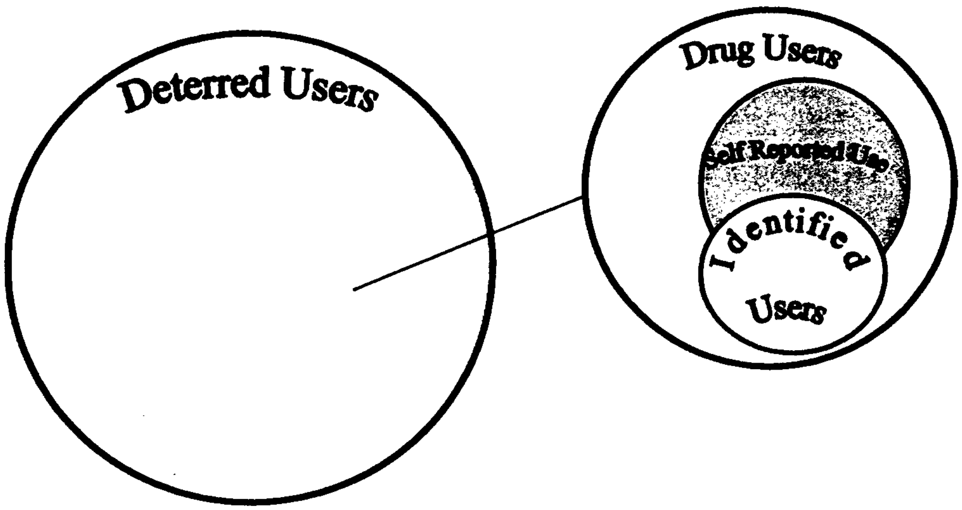


Figure 8, below represents the same population of Marines prone to illicit drug use, however, under-reporting is accounted for by representing self-reported use as a portion of actual drug users. Figure 8 is more representative of the true model of the current Marine Corps urinalysis program because it identifies a variation in the quantity of self-reported drug users and actual drug users. The hypothesized model in Figure 8 also illustrates a decrease in the proportion of deterred users; the number of actual users is hypothesized to be significantly greater than the number of self-reported users, thereby decreasing a population that is considered deterred (non-drug using).

Figure 8. Population of Marines Prone to Illicit Drug Use (Accounting for Under-Reporting) Urinalysis Model

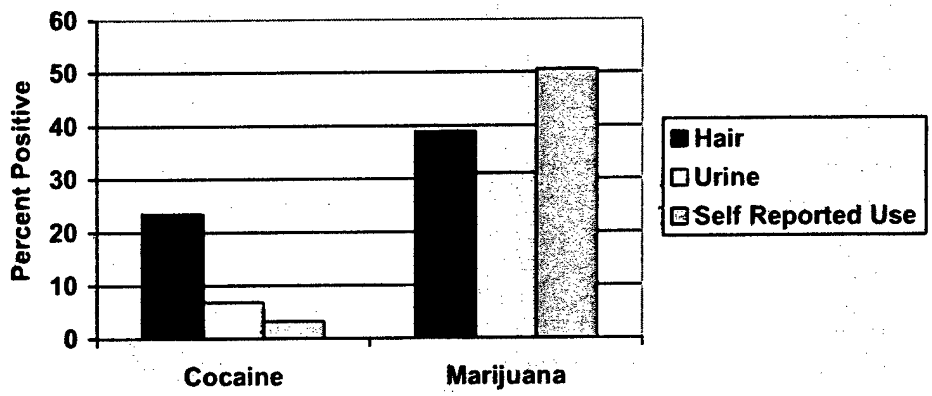


Figures 9, 10, and 11 illustrate a wide discrepancy between self-reported drug use and actual drug use in populations of juvenile arrestees. This discrepancy is especially evident in cocaine detection and self-report levels. The population used for the data illustrated in Figure 12 is most representative of the population of Marines and is therefore the basis of the hypothesis that self-reported use is significantly different than actual use. The focus of Figure 12 is to illustrate the discrepancy between self-reported use and detected use—this figure does not sufficiently represent comparative effectiveness of the hair test and urinalysis, as the number of drugs and the population tested for the urinalysis and hair test vary.

Figures 9 and 10 also bring to light interesting characteristics of the hair test and urinalysis in regard to marijuana detection. Whereas the hair test appears more effective for marijuana use in Figure 9, the urinalysis appears more effective in Figure 10. Also, it is notable that self-report levels for marijuana use were higher than detection levels in Mieczkowski et al (1998) and Mieczkowski and Newel (1993). Mieczkowski and Newel state, in regard to over-reporting marijuana use, "Why this is so is not well understood, but this pattern has been reported previously."(p. 64) Figures 9 and 10 illustrate that for cocaine testing, the proportion of persons detected by the hair test greatly contrasts both

self-reported use levels and urinalysis detection levels. There are no studies that present information contrary to this fact.

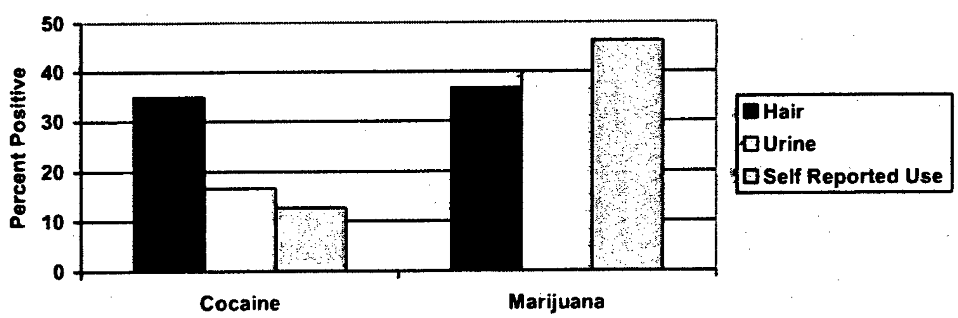
Figure 9. Comparison of Urine, Hair, and Self Reported Use of Cocaine and Marijuana (Juvenile Arrestees 1998)



Notes: n=346 for cocaine test
n=326 for marijuana test
Sensitivity of hair test>2ng/mg

Adapted from "Using hair analysis, urinalysis, and self-reports to estimate Drug Use in a Sample of Detained Juveniles" by T. Mieczkowski, R. Newel, and B. Wraight, 1998, Substance Use & Misuse, 33(7), pp.1558 and 1561. Copyright 1998 by Marcel Dekker, Inc.

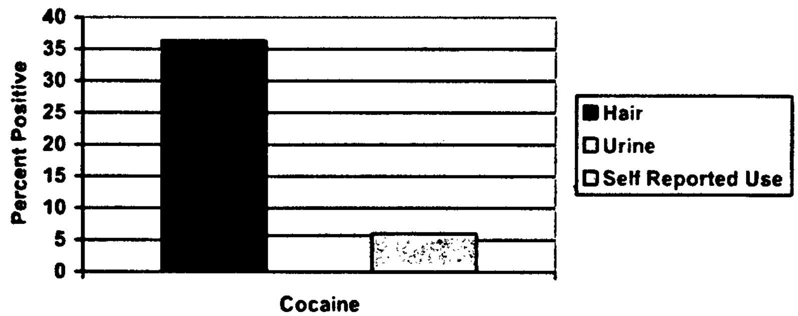
Figure 10. Comparison of Urine, Hair, and Self Reported Use of Cocaine and Marijuana (Juvenile Arrestees 1993)



Notes: n=860 for cocaine test
n=572 for marijuana test
Sensitivity of hair test >5ng/mg
Length of hair approximately 2.6 cm
Self reported cocaine use in last 60 days
Self reported marijuana use in last 30 days not available

Adapted from "Comparing hair and urine assays for cocaine and marijuana" by T. Mieczkowski and R. Newel, 1993, Federal Probation, 57, pp 66-67.

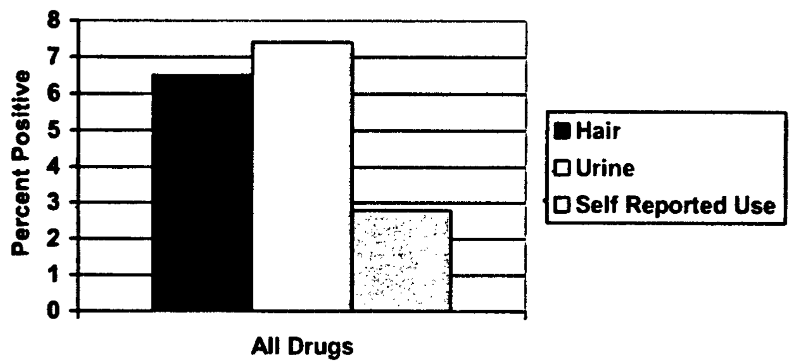
Figure 11. Comparison of Hair, Urine, and Self Reports for Cocaine Use (Juvenile Arrestees 1994)



Notes: n=88
Sensitivity of hair test >2ng/mg
Length of hair approximately 2.5 cm
Self reported use in lifetime

Adapted from "Drug use among juvenile arrestees: a comparison of self-report, urinalysis and hair assay" by T. Feucht and R. Stephens, 1994, Journal of Drug Issues, 24, p. 108.

Figure 12. Comparison of Urine, Hair, Self Report of All Drugs (Steelworkers, 1995)



Notes: n=307 for hair test
n=637 for urinalysis
Sensitivity of hair test>5ng/10 mg hair
Length of hair approximately 2.5 cm
Self reported use in last 30 days
Urinalysis tested for two additional drug types (sedatives, tranquilizers)

Adapted from "Methods for assessing drug use prevalence in the workplace: a comparison of self-report, urinalysis, and hair analysis" by R. Cook, M. Bernstein, C. Andrews, and G. Marshall, 1995, The International Journal of the Addictions, 30(4), p. 415. Copyright 1995 by Marcel Dekker, Inc.

If a reasonable deterrence effect of the hair test can be applied to a cost and benefit estimate, the disparity between self-reported use and actual use must first be recognized. With this in mind, the deterrence levels of the urinalysis suggested by McCrea and Hey (2001), Diddams (1999), Martinez (1998) and Borack (1997) will be significantly decreased, as the number of actual users (undeterred users) is significantly greater when the number of non-reported users is accounted for. The monetary benefits of the urinalysis program, based on inflated deterrence levels, are also impacted. The proportion of identified users, self-reported users, and non-reported users will all substantially decrease with an increase in the proportion of deterred users. Cook et al (1995) suggest that actual drug use among a population similar to the population of the Marine Corps may be 50% higher than self-reported use. It can be reasonably estimated that actual drug use among Marines is 20%-50% higher than the self-reported use identified by the DODWWS.

2. Analysis of Effects of Increased Sensitivity on Deterrence

Table 8, below, illustrates Borack's (1997) finding that doubling drug test sensitivity positively affects deterrence. According to Borack (1997), given a 20% chance of being tested during a given month (20% monthly test rate), doubling the sensitivity of the test increases the deterrence level by 9%. It is estimated that the hair test will meet or exceed the 9% increase in deterrence given the dramatic increase in sensitivity and relative immunity to gaming of the hair test for a wide range of illicit drugs. Table 8 illustrates the impact on deterrence of doubling the sensitivity of a drug test suggested by Borack (1997). Table 9 illustrates the combined effect of detection and deterrence by doubling the sensitivity of a drug test. Note that at the 20% monthly test rate, Borack (1997) suggests that 67.8% of the population prone to illicit drug use will either be identified or deterred by a test with double the sensitivity.

Table 8. Impact of Monthly Test Rate and Test Sensitivity on Deterrence

Monthly Test Rate (%)	Proportion Deterred	Increased Sensitivity Proportion Deterred
0	0.00	0.00
5	0.26	0.32
10	0.4	0.48
15	0.5	0.58
20	0.57	0.66
25	0.63	0.72
30	0.68	0.77
35	0.72	0.81
40	0.76	0.85

Note: Monthly test rate is the percentage chance a person will get tested for drugs in a given month

Adapted from "A technique for Estimating the Impact of Improvements in Drug Testing Sensitivity on Detection and Deterrence of Illicit Drug Use by Navy Personnel" by J. Borack, 1997, Navy Personnel Research and Development Center, San Diego, California, p. 10.

Table 9. Number of Users Deterred or Detected in a Month (Per 1000 Users)

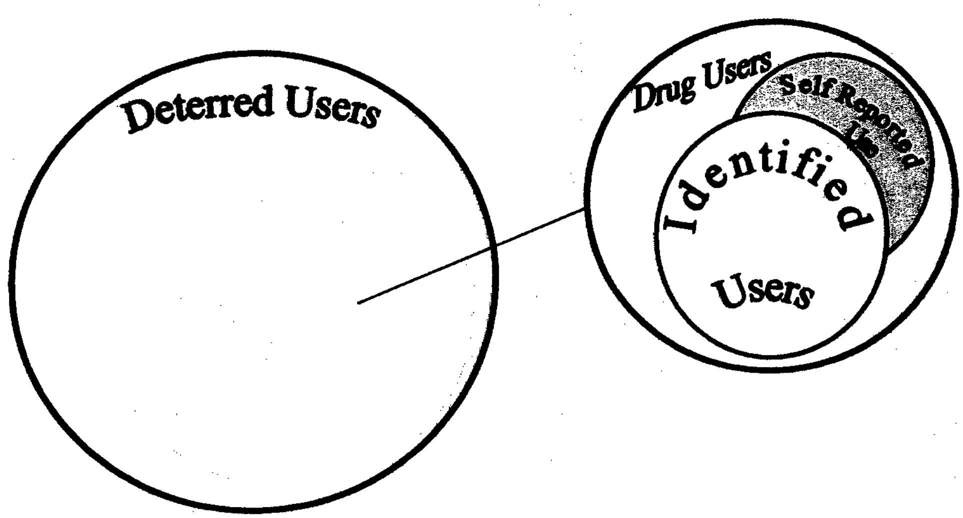
Monthly Test Rate (%)	Number Deterred or Detected	Increased Sensitivity Number Deterred or Detected
0	0	0
5	269	330
10	416	492
15	516	599
20	592	678
25	652	739
30	702	789
35	744	831
40	780	866

Note: Monthly test rate is the percentage chance a person will get tested for drugs in a given month

Adapted from "A technique for Estimating the Impact of Improvements in Drug Testing Sensitivity on Detection and Deterrence of Illicit Drug Use by Navy Personnel" by J. Borack, 1997, Navy Personnel Research and Development Center, San Diego, California, p. 11.

Figure 13 is a hypothetical model that illustrates the initial impact the hair test would have on the relationship between identified users, self-reported users, and actual users in a population of Marines. This model represents a significant increase in the number of identified drug users after the initial implementation of the hair test. Note that the number of identified users encompasses the majority of self-reported users and includes a greater portion of the drug-using population. The proportion of drug users and deterred users is hypothesized not to change until a reasonable period when the population of Marines prone to illicit drug use realizes the increased effectiveness of the hair test. The increase in identified users may be so great that a change in the "zero tolerance" policy may be unavoidable. These hypotheses were developed based upon the findings of Borack (1997), Diddams (1999), McCrea and Hey (2001), and Martinez (1998), who all illustrate that the percentage of identified users (approximately 1%) is much smaller than the number of self-reported users (approximately 6%), based upon the self-report DODWWS and NHSDA.

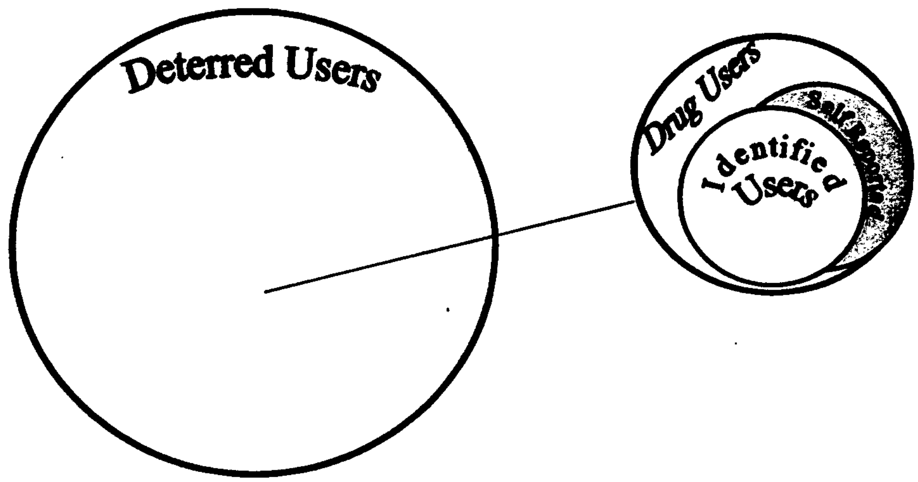
Figure 13. Population of Marines Prone to Illicit Drug Use (Hair Test Initial Impact Model)



Whereas Figure 13 represents the initial impact the hair test will have on detection and deterrence, Figure 14 represents the long-term impact of hair testing on detection and deterrence. The deterrent effects of a hair test will not be realized until the hair test is implemented and the probability of drug detection is increased. Note that Figure 14

exhibits an increase in the number of deterred users and a proportional decrease in the number of drug users. This model represents the primary benefit hair testing is expected to offer: increased deterrence and decreased drug use. Decreased drug use would also correspond to a net decrease in detection and a decrease in self-reported use.

Figure 14. Population of Marines Prone to Illicit Drug Use (Hair Test Long-Term Impact Model)



It appears that the hair test would effectively deter illicit drug use by Marines, considering the apparent relationship between drug testing and deterrence. It also appears that the hair test would significantly increase the number of Marines deterred from illicit drug use, considering the apparent relationship between increased drug test sensitivity and increased deterrence. If it is assumed that self reported drug users represent the entire population of drug users, the perceived number of deterred users in a population prone to illicit drug use would be over-represented. However, self-reported drug users may represent just a portion of the actual drug using population; the actual number of deterred users in a population prone to illicit drug use would be much smaller when considering under-reporting on self-reported surveys. The hair test appears capable of both increasing deterrence and decreasing the actual drug-using population among a population of Marines prone to illicit drug use.

V. COST EFFECTIVENESS

The following chapter will generate a cost and benefit estimate from implementing the hair test in order to determine whether the costs of the hair test would be comparable or less than the urinalysis if utilized by the Marine Corps. Detection and deterrent characteristics of the hair test, examined in Chapters III and IV, will be applied to a cost benefit study (McCrea & Hey, 2001) that investigated the Navy's urinalysis program. Additionally, the effects of under-reporting will be considered in the cost and benefit estimates that are generated. A review of the McCrea and Hey (2001) study will be followed by an analysis of the cost and benefits of the hair test.

A. REVIEW OF COST/BENEFIT STUDY OF DRUG TESTING PROGRAM

McCrea and Hey (2001) completed a thesis titled, "An Evaluation of Costs and Benefits of the Navy's Drug Detection Program". The issues brought forth by this study will be the foundation of cost examination portion of this thesis as it will offer a broad foundation on which to base comparisons with the effects of implementing a hair test. McCrea and Hey (2001) suggest that there are three factors which affect the cost effectiveness of the urinalysis program: the degradation factor, net detection effect, and deterrence effect. Using data from the DODWWS and NHSDA surveys from 1979/1980, 1985, and 1995, McCrea and Hey conducted an analysis of the deterrent effect of the Navy's drug detection policy, similar in scope to Diddams (1999) and Martinez (1998). The limitations of the DODWWS and NHSDA self-report surveys also exist with the McCrea and Hey (2001) thesis. McCrea and Hey researched the negative impact drugs had on workplace performance levels, or the degradation factor, from various studies. The degradation factors were then applied to the net detection effect (the number of Sailors found positive on the urinalysis) and deterrence effect (Sailors who avoided drugs because of the urinalysis) to produce estimates of cost and benefits. The most valuable material from this thesis is the suggested relationships of the deterrence effect, degradation factor, and detection effect. However, some shortfalls, described below,

exist in the use of data that greatly under-represents the level of monthly deterrence attributed to the Navy's urinalysis program.

A deterrence factor is a proportion that quantifies the level of deterrence that can be attributed to the urinalysis program. If the probability of a serviceman using drugs during a given period is less than the probability of a civilian during the same period, the difference is attributed to deterrence effect of a urinalysis. The deterrence factor is derived from comparing estimates (coefficient estimates from logistic specifications) of the probability of using any illicit drug in the past year or past month by a civilian and a serviceman. (McCrea & Hey, 2001) The deterrence factor is a key element in McCrea and Hey's (2001) thesis that investigates the cost effectiveness of the Navy's drug policies. Although no studies have been conducted that investigate the magnitude of the hair test's deterrence factor, it is hypothesized that, given the increased sensitivity of the hair test, the deterrence factor of the hair test would be significantly greater than the urinalysis deterrence factor. A range of estimated deterrence factors for the hair test is generated, based upon urinalysis deterrence factors developed in previous studies and in consideration of the frequency of under-reporting that is expected to occur.

McCrea and Hey (2001) used a detection factor to quantify the number of personnel who were found to be drug positive on a urinalysis and subsequently discharged. The detection factor is the percentage of personnel detected and discharged in a given population. The population used by McCrea and Hey (2001) is the Navy's end strength in FY99, or 314, 272 personnel. In FY99, 5,416 Navy personnel were detected for drug use and were subsequently discharged, resulting in a detection factor of 1.72%.(McCrea & Hey, 2001) Since some drug users will be among those recruited to replace the discharged personnel, the net detection factor is estimated to be approximately 4% less than the number of personnel actually positively detected annually.(McCrea & Hey, 2001) In FY99 when 5,416 discharged personnel needed to be replaced, McCrea and Hey (2001) suggest that 4% of the 5,416 personnel recruited (247 personnel) are drug users. If a hair test were used, the impact on the detection factor is hypothesized to be twofold. First, the number of personnel in the Marine Corps detected is hypothesized to increase. Second, the number of recruits who are attempting to enter the Marine Corps with an existing drug problem will likely be more readily

identified prior to entering the service. This would lead to a decrease in the number of drug-using recruits, thereby reducing the 4% figure suggested by McCrea and Hey (2001), subsequently increasing the net detection factor. It is therefore hypothesized that the hair test net detection factor would be significantly greater than the urinalysis net detection factor when the hair test is first implemented. Given the hypothesized positive effects of deterrence over a period of time, the detection factor would likely decrease over time as the number of personnel who are deterred increases. An estimated value of the net detection factor is generated for the hair test by examining the results of studies that researched increased sensitivity detection levels and comparative detection levels of urinalyses and hair tests.

The "replacement assumption" listed in Table 10, below, depicts two different methods of estimating the cost of replacing Sailors who have been dismissed for drug use. 1 for 1 replacement costs were derived by using the Cost of Manpower Estimation Tool (COMET). "COMET is a software tool that would enable the user to more accurately estimate the total, marginal, and average costs of filling the Navy's active billets."(McCrea & Hey, 2001, p. 68). COMET was used to calculate the average cost of replacing Sailors by considering pay grade, specialty, items funded by Military Personnel, variable indirect personnel costs, and other non-Navy costs.(McCrea & Hey, 2001, pp. 68-69) The agricultural replacement assumption, however, reflects the number of people it takes to "grow" into the pay grades of those discharged. The agricultural theory therefore, accounts for survival rates of each pay grade being replaced and accounts for the attrition that occurs prior to entering those pay grades. Agricultural replacement is more expensive than 1 for 1 replacement because it is involves a larger population of recruits that need to be appropriately trained and developed to fulfill the positions they would be holding.

The degradation factor is a quantified proportion that researchers have developed to quantify the loss in productivity of an employee who uses drugs. The degradation factor value is constant, regardless of which test is used to detect drug use. It is therefore hypothesized that the degradation factor would be unchanged when applied to a hair test or a urinalysis. The same values of the degradation factors that McCrea and Hey (2001) used to base their cost analysis of the Navy's drug policies will be applied to estimated

hair testing deterrence and detection factors to provide a general estimate of cost or benefit if the hair test were to be employed by the Marine Corps.

Table 10. Summary Cost-Benefit Analysis. Past Month Participation (millions of dollars)

Replacement Assumption	Total Cost	Gross Benefits Degradation Factor			Net Benefit/Loss Degradation Factor		
		Low[a]	Mean[b]	High[c]	Low[a]	Mean[b]	High[c]
1 for 1	$90	$13.7	$42.1	$126.3	-$76.3	-$47.9	+$36.3
Agriculture	$196	$13.7	$42.1	$126.3	$-182.3	-$153.9	-$69.7

Notes: All numbers in millions
Average annual Regular Military Compensation (RMC) = $22,745
N (replacement) = 5,416
N(detection effect) = 5,199
N(deterrence effect) = 2,451
[a] Degradation factor (low) = -0.079
[b] Degradation factor (mean) = -0.242
[c] Degradation factor (high) = -0.726

Adapted from "An Evaluation of Costs and Benefits of the Navy's Drug Prevention Policies" by M. McCrea and M. Hey, 2001, Master's Thesis, Naval Postgraduate School, Monterey, California, p. 101.

The degradation factors listed above represent the percentage production loss by an employee who is an illicit drug abuser. If the degradation factor were zero, that would indicate that drug abuse has no impact on the productivity of a serviceman. In the Navy and Marine Corps, where tangible products are most often impossible to measure, the value of production degradation is debatable. However, for the purposes of this study, it is assumed that drug abuse does impact productivity to some degree. McCrea and Hey (2001) provide three degradation values ranging from low impact to high impact, that they found through research. They then applied the values to the following formula to produce the amount of degraded productivity, in terms of regular military commission (RMC), that is avoided by detection and deterrence:

(detection effect + deterrence effect) * (degradation factor) * RMC = GrossBenefit

Gross benefits were then subtracted from the value of each replacement assumption ($90 million and $196 million) to produce Net Benefit.

There is a discrepancy in the levels of deterrence and drug use in McCrea and Hey's (2001) study. First, they state that the annual deterrence rate attributable to the urinalysis program is -9.76 percentage points based on the difference between civilian and servicemen drug use rates. Then they state that about 5% of the Navy personnel used drugs within the past year during 1995. However, when determining the *monthly* deterrence rate attributable to the urinalysis program, they arrive at a value of –0.78 percentage points—a value that does not compare the difference between civilian and servicemen drug use rates. Further, they state that about 3% of the Navy personnel used drugs within the past year during 1995; whereas, earlier in their report, they state 5% of the Navy personnel used drugs during 1995.(McCrea & Hey, 2001, p. 96, 100-101) Aside from the discrepancy of annual drug use rates, a more significant problem exists in the value used for the deterrence effect for past month participation. Table 11 suggests that past month deterrence effect percentage value for 1995 was –6.02 not –0.78. In fact, the value of –0.78 represents the difference in marginal effects percentage between 1995 and 1979/80 (-6.0238 minus –5.248). The difference-in-difference values are listed in Table 12. It is also unclear why McCrea and Hey (2001) used annual costs and monthly benefits to arrive at their net cost/benefit figures.

Table 11. Logit Estimates of Military Coefficient in Drug Participation Models, 1995 Data, Restricted Samples, by Branches (Marginal Effects)

	Ages 17-49 (Navy)	Ages 17-34 (Navy)	Ages 17-25 (Navy)
Past Year Participation	-9.763	-11.851	-12.884
Past Month Participation	**-6.0238**	-7.496	-8.766

Note: Values depict drug participation probability percentage when compared to baseline predicted probability of civilians

Adapted from "An Evaluation of Costs and Benefits of the Navy's Drug Prevention Policies" by M. McCrea and M. Hey, 2001, Master's Thesis, Naval Postgraduate School, Monterey, California, p. 47.

Table 12. Difference-in-Difference (1979/80 – 1995) (in percentage points)

	Ages 17-49 (Navy)	Ages 17-34 (Navy)	Ages 17-25 (Navy)
Past Year Participation	-14.416	-18.23	-22.535
Past Month Participation	**-0.7758**	-1.881	-4.013

Note: Values depict the difference in Marginal Effects Values from 1995 and 1980

Adapted from "An Evaluation of Costs and Benefits of the Navy's Drug Prevention Policies" by M. McCrea and M. Hey, 2001, Master's Thesis, Naval Postgraduate School, Monterey, California, p. 48.

McCrea and Hey used –0.78 percentage points to produce the number of deterred users in 1999 by applying this value to the Navy's end strength in 1999. The formula used was:

(deterrence effect percentage) * Navy End Strength = number of deterred users

(-0.78) * 314,272 = 2, 451 deterred users

The number of deterred users (deterrence effect) was then applied to the Gross Benefit formula listed above, therefore greatly under-representing both Gross and Net Benefits. The number of deterred users each month is under-represented by 16,480 personnel, which relates to millions of dollars in avoided costs. The under-representation of the number of deterred users for past month participation has impact on the validity of McCrea and Hey's (2001) findings, when considering the large differences in the revision illustrated in Table 13. McCrea and Hey (2001) suggest, based partly upon their erroneous monthly deterrence figures, that a high degradation factor is necessary to justify the urinalysis program.(p. 106) This is not necessarily true if revised deterrence figures are used.

Applying the correct marginal percentage value for deterred users, past month participation, to the number of deterred users formula produces 18, 931 deterred users.

(-6.02) * 314, 272 = 18, 931 = deterrence effect

Applying the revised deterrence effect to the degradation factors in Table 11 produces the results illustrated in Table 13, a revised summary cost-benefit analysis of past month drug use:

Table 13. Revised Summary Cost-Benefit Analysis. Past Month Participation (millions of dollars)

Replacement Assumption	Total Cost	Gross Benefits Degradation Factor			Net Benefit/Loss Degradation Factor		
		Low[a]	Mean[b]	High[c]	Low[a]	Mean[b]	High[c]
1 for 1	$90	$43.4	$132.8	$398.5	-$46.6	+$47.9	+$308.5
Agriculture	$196	$43.4	$132.8	$398.5	$-152.6	-$63.2	+$202.5

Notes: All numbers in millions
Average annual Regular Military Compensation (RMC) = $22,745
N (replacement) = 5,416
N(detection effect) = 5,199
N(deterrence effect) = 18, 931
[a] Degradation factor (low) = -0.079
[b] Degradation factor (mean) = -0.242
[c] Degradation factor (high) = -0.726

Adapted from "An Evaluation of Costs and Benefits of the Navy's Drug Prevention Policies" by M. McCrea and M. Hey, 2001, Master's Thesis, Naval Postgraduate School, Monterey, California, p. 101.

The approach McCrea and Hey took to capture an extremely difficult value of cost is commendable. The relationships, considerations, and concerns developed by McCrea and Hey are referred to throughout this thesis and form the framework of cost estimations of the hair test for a similar population. However, McCrea and Hey's thesis generates questionable values for monthly deterrence and cost estimates, described above, which brings question to their overall numerical estimates and general conclusions.

B. ANALYSIS OF COST EFFECTIVENESS HAIR TEST VS URINALYSIS

The model used to determine the relative costs of the hair test will be the model suggested by McCrea and Hey (2001) when they determined the annual costs and benefits of the urinalysis. The primary variables that will be affected by the hair test are

the cost of implementing the program, the detection effect, and the deterrence effect. Based upon the increased cost of administering the hair test that is suggested by Pyschemedics Corporation, it is estimated that the cost of hair testing is approximately 60% higher than the current \$17.5 million annual cost (McCrea and Hey (2001)) of administering the urinalyses. This is an increase in total cost of \$11.7 million annually.

The detection effect is estimated to increase by about one third, considering the increased sensitivity of the hair test and the relative immunity to gaming of the hair test. McCrea an Hey (2001) found that in 1999, the Navy's detection rate was 1.72%, corresponding to 5,416 personnel detected and discharged due to drug use.(McCrea and Hey, 2001, p. 94) Increasing the detection rate by one third would result in a detection rate of 2.29%, or 7,196 personnel using the Navy's end strength in 1999. Assuming, as did McCrea and Hey (2001), that "approximately 4% of those who replace the discharged personnel are drug users"(p. 95) the net detection rate is reduced to 2.2% since 288 of the 7, 196 servicemen needed to replace discharged personnel are discharged themselves.

$$.0229 * 314{,}272 = \text{detection effect} = 2.29\%$$

$$7{,}196 - (7{,}196 * .04) = 6{,}908 = \text{net detection effect} = 2.20\%$$

The deterrence effect is estimated to increase by 9%. Applying the new figures to McCrea and Hey's (2001) deterrence effect estimation from 1995 data, results in an increased monthly deterrence effect from 6.2% to 15.2%. Using the Navy's end-strength from 1999, the deterrence effect results in an increase from 18,931 deterred users to 47,769 deterred users.

$$.152 * 314{,}272 = 47{,}769 = \text{deterrence effect}$$

Comparative results of the urinalysis, as was previously presented in Table 13, are shown in parenthesis in the Table 14, below. If the estimated changes in deterrence, detection, and administrative costs are applied to the monthly cost benefit model suggested by McCrea and Hey (2001), the resulting cost and benefits of the hair test for a given month are dramatically different, as shown below in Table 14. Annual cost figures were used for Table 14 to maintain consistent cost value proportions when comparing the hair test and urinalysis

Table 14. Revised Summary Cost-Benefit Analysis of Hair Test. Past MONTH Participation
(millions of dollars)

Replacement Assumption	Total Cost	Gross Benefits Degredation Factor			Net Benefit/Loss Degredation Factor		
		Low[a]	Mean[b]	High[c]	Low[a]	Mean[b]	High[c]
1 for 1	$101.7 ($90)	$98.2 ($43.4)	$300.9 ($132.8)	$902.9 ($398.5)	-$3.5 (-$46.6)	+$199.2 (+47.9)	+$801.2 (+$308.5)
Agriculture	$207.7 ($196)	$98.2 ($43.4)	$300.9 ($132.8)	$902.9 ($398.5)	$-109.5 ($-152.6)	+$93.2 (-$63.2)	+$695.2 (+202.5)

Notes: All numbers in millions
Average annual Regular Military Compensation (RMC) = $22,745
N (replacement) = 7,196
N(detection effect) = 6,908
N(deterrence effect) = 47,769
[a] Degradation factor (low) = -0.079
[b] Degradation factor (mean) = -0.242
[c] Degradation factor (high) = -0.726
Urinalysis values in parenthesis

Adapted from "An Evaluation of Costs and Benefits of the Navy's Drug Prevention Policies" by M. McCrea and M. Hey, 2001, Master's Thesis, Naval Postgraduate School, Monterey, California, p. 101.

Table 14 suggests that if the hair test were used during the period when McCrea and Hey (2001) collected their data, a significant increase in avoided costs would result in a more cost-effective program. However, as was mentioned earlier, the approximate self-reported annual use suggested by McCrea and Hey (2001) and Martinez (1998) of 5% is estimated to be 20%-50% less than actual use. This corresponds to 6%-7.5% of the members of the Naval Service actually used drugs within the past year (versus the approximate 5% suggested by McCrea and Hey (2001)). Applying this revised actual drug use figure to McCrea and Hey's (2001) model would result in a deterrence effect of 7.26%-8.76%. This estimated range of deterrence effects is considerably smaller than the 9.76% figure proposed by McCrea and Hey (2001). Applying the deterrence effects of 7.26%-8.76% to the Navy's end strength results in a range of 22,816 to 27,530 deterred users each year, compared to the 30,673 deterred users proposed by McCrea and Hey (2001). Applying the estimated range of deterred users to the Summary Cost Benefit Analysis for past year drug use that was suggested by McCrea and Hey (2001) when determining urinalysis cost effectiveness results in the following range of costs, as listed in Table 15.

The values shown in Table 15 illustrate the negative impact that under-reporting can have on the estimated costs and benefits associated with the urinalysis. It is important to note that under-reporting drug use can have a visible effect on the perception

Table 15. Revised Summary Cost-Benefit Analysis Considering Under-Reporting. URINALYSIS Past YEAR Participation (millions of dollars)

Replacement Assumption	Total Cost	Gross Benefits Degredation Factor			Net Benefit/Loss Degredation Factor		
		Low[a]	Mean[b]	High[c]	Low[a]	Mean[b]	High[c]
1 for 1	$90	($64.4)	($197.4)	($592.0)	(-$25.6)	(+$107.4)	(+$502.0)
Revised Low		$50.3	$154.2	$462.6	-$39.7	+$64.2	+$372.6
Revised High		$58.8	$180.1	$540.4	-$27.6	+$90.1	+$450.4
Agriculture	$196	($64.4)	($197.4)	($592.0)	($-131.6)	(+$1.4)	(+$396.0)
Revised Low		$50.3	$154.2	$462.6	-$145.7	-$41.8	+$266.6
Revised High		$58.8	$180.1	$540.4	-$137.2	-$15.9	+$344.4

Notes: All numbers in millions
Average annual Regular Military Compensation (RMC) = $22.745
N (replacement) = 5,416
N(detection effect) = 5,199
N(deterrence effect) = 30,673 (0 drug users did not self-report use, values in parenthesis)
N(deterrence effect. Low Est) = 22,816 (50% drug users did not self-report use)
N(deterrence effect. High Est) = 27,530 (20% drug users did not self-report use)
[a] Degradation factor (low) = -0.079
[b] Degradation factor (mean) = -0.242
[c] Degradation factor (high) = -0.726

Adapted from "An Evaluation of Costs and Benefits of the Navy's Drug Prevention Policies" by M. McCrea and M. Hey, 2001, Master's Thesis, Naval Postgraduate School, Monterey, California, p. 100.

of positive deterrence. The Revised Low estimates reflect the impact on deterrence and cost if 50% of the actual users did not self-report drug use. The Revised High estimates reflect the impact on deterrence and cost if 20% of the actual users did not self-report drug use. If the estimated 33% increase in detection and 9% increase in deterrence levels expected from a hair test are applied to McCrea & Hey's (2001) model for annual use, a general comparison in cost can be generated.

Table 16 illustrates the outcome of an increase in detection levels by one third and an increase in deterrence of 9% from using the hair test. It is clear that the enhanced detection and deterrence characteristics of the hair test will have a profound impact on the cost of the Navy and Marine Corps drug testing program. Even when accounting for up to 50% under-reporting of drug use, implementation of a hair test would have a dramatic impact on the estimated costs and benefits of the drug program.

Table 16. Revised Summary Cost-Benefit Analysis Considering Under-Reporting. HAIR TEST Past Year Participation (millions of dollars)

Replacement Assumption	Total Cost	Gross Benefits Degredation Factor			Net Benefit/Loss Degredation Factor		
		Low[a]	Mean[b]	High[c]	Low[a]	Mean[b]	High[c]
1 for 1	$101.7						
Hair Low		$104.2	$319.3	$957.9	+$2.5	+$217.6	+$856.2
Hair High		$112.7	$345.2	$1,036	+$11.0	+$243.5	+$934.3
Agriculture	$207.7						
Hair Low		$104.2	$319.3	$957.9	-$103.5	+$111.6	+$750.2
Hair High		$112.7	$345.2	$1,036	-$95.0	+$137.5	+$828.3

Notes: All numbers in millions
Average annual Regular Military Compensation (RMC) = $22,745
N (hair replacement) = 7,196
N(hair detection effect) = 6,908
N(hair deterrence effect, Low Est) = 51,100 (50% drug users did not self-report use)
N(hair deterrence effect, High Est) = 55,814 (20% drug users did not self-report use)
[a] Degradation factor (low) = -0.079
[b] Degradation factor (mean) = -0.242
[c] Degradation factor (high) = -0.726

Adapted from "An Evaluation of Costs and Benefits of the Navy's Drug Prevention Policies" by M. McCrea and M. Hey, 2001, Master's Thesis, Naval Postgraduate School, Monterey, California, p. 100.

The enhanced deterrent effect of the hair test, developed in Chapter IV, has great impact on the avoided costs of associated with deterring illicit drug use. Because the hair test is expected to increase deterrence, the benefits of the hair test should far transcend the benefits of the urinalysis, as illustrated in this chapter. Even considering the added costs associated with the increased complexity of the hair test and the impact of under-

reporting, the hair test appears to be more cost effective than the urinalysis under every replacement assumption and every estimated level of degradation. Detection, deterrence, and cost are all inter-related and appear to be strongly dependent upon the robustness of the test used. The results in this chapter strongly suggest that deterrence offers the greatest monetary benefits to an organization and correspondingly, the hair test's deterrent characteristics would result in a more cost effective drug testing program.

VI. CONCLUSIONS & RECOMMENDATIONS

This thesis examined whether the hair test is a feasible method of detecting illicit drug use in the United States Marine Corps. The hair test is considered feasible in this study if the following conditions were met:

1. Hair testing can effectively detect illicit drug use
2. Hair testing can effectively deter drug use
3. The costs of hair testing are comparable or less than the urinalysis
4. The hair test is fair to all Marines

To determine whether the hair test is feasible, studies that investigated the detection properties of the hair test were examined. The detection level of the hair test was compared to the detection level of the urinalysis by examining studies that performed tandem urinalyses/hair tests on various populations. Analysis of these studies generated an estimated level of detection of the hair test, relative to the urinalysis. Analysis of these studies also disclosed the relationship of detection and bias. Based upon the increased sensitivity of the hair test, an estimated level of deterrence was generated by examining studies that investigated the deterrent effects of drug testing programs. Using both the detection and deterrence estimates of the hair test, a cost and benefit estimate was generated. This chapter will first provide a summary of the main findings and will then provide recommendations for the implementation of the hair test in the Marine Corps. The limitations of this study will be addressed, as well as final conclusions.

A. SUMMARY OF FINDINGS

Analysis of the studies examined in this thesis suggests that the hair test can effectively detect and deter drug use among Marines in a fair and cost effective manner. In fact, the results of this study suggest that the hair test would greatly enhance detection levels of the Marine Corps' drug detection program, thereby increasing deterrence and reducing the costs attributable to drug abuse. The results of this study also suggest that the hair test would be no more race biased than the urinalysis, but would however, accentuate illicit drug use preferences among different races.

Analysis of a wide variety of studies that investigated the detection effectiveness of the hair test indicates that the hair test would be approximately 33% more effective at detecting illicit drug users. This estimate was derived from analyzing comparative studies of the urinalysis and hair test along with a study that investigated the impact of increased drug test sensitivity. It is clear from data analysis that the results of the hair test far surpass the results of the urinalysis in detecting cocaine, opiates, and amphetamines. However, the ability of the hair test in detecting marijuana does not appear to generate any favorable advantage over the urinalysis.

The ability of the hair test to detect cocaine, opiates, and amphetamines results in a greater number of illicit drug users identified for those specific drugs than would occur with the urinalysis. The proportion of each race identified for drug use is not likely to be representative of the proportion of each race in the population tested; this may be especially true when examining the proportion of each race identified for specific drugs. The data presented in this thesis suggests that the hair test identifies proportionally over-represented races positively detected for specific drugs. However, because the urinalysis reflects similar proportions, the hair test likely identifies different drug preferences among different races. The hair test does not appear to be overly sensitive or ineffective to one race or another.

The result of examining various studies that investigated deterrence strongly suggests that deterrence is significantly related to the sensitivity and frequency of a drug testing. One study in particular, Borack (1997), examined that relationship of increased urinalysis sensitivity on deterrence and suggested that doubling the sensitivity of a drug test resulted in increased deterrence. Since no studies are available that estimate the deterrent properties of a hair test, an estimate of the deterrence level of the hair test was derived from analyzing the deterrent effects of the urinalysis and the increased sensitivity study conducted by Borack (1997). It is estimated that the hair test would increase the level of drug deterrence by approximately 9%, based upon analysis of data offered by studies examined in this thesis.

An estimate of the cost effectiveness of the hair test was developed, based upon a cost and benefit estimate of the Navy's urinalysis program proposed by McCrea and Hey

(2001). Estimated increased costs of the hair test were considered and applied to the urinalysis model. Additionally, estimates of the number of persons who are actual drug users (undeterred) were provided to better estimate the level of deterrence. Applying these estimations to the McCrea and Hey (2001) model resulted in a net benefit/loss of the hair test ranging from -$103.5 million to +856.2 million annually assuming 20%-50% of the population under-reported drug use. On the other hand, McCrea and Hey (2001) suggest a net benefit/loss range for the urinalysis of -$131.6 million to +$502.0 million annually *assuming 0% under-reported drug use.* Even when the negative impacts of under-reporting are applied to the hair test and not the urinalysis, the hair test net benefits are substantially greater than the urinalysis. It can therefore be reasonably asserted that the hair test would be equally or more efficient than the urinalysis.

The different characteristics of the hair test and urinalysis present strengths and weaknesses if either test is used alone. However, if the tests are used in tandem the different characteristics, often complementary, can present a more comprehensive illustration of a person's drug use history. Whereas the hair test uncovers a long-term drug use history, the urinalysis uncovers a short-term drug use history. Whereas the hair test is not a proven identification method for marijuana use, the urinalysis is a proven method of efficiently detecting the metabolites of marijuana. However, although the urinalysis can efficiently detect marijuana use, it is much more vulnerable to gaming than the hair test. The relative effectiveness of the urinalysis for marijuana, then, can be greatly diminished. Table 17, below, summarizes the strengths and weaknesses of each test.

Assuming the hair test is a feasible method of detecting illicit drug use among Marines, the best test method for the Marine Corps to use is dependent upon several factors. The first factor is the drug targeted for random detection. If marijuana is the primary drug targeted for illicit drug use, it appears that the urinalysis would satisfactorily detect a significant number of drug users, although gaming would continue to impact detection levels. If, on the other hand, cocaine, amphetamines, and opiates are the primary drugs targeted for random detection, it appears that a hair test would profoundly impact detection levels with minimal impact from gaming, thereby being the

Table 17. Summary Comparison Hair Test and Urinalysis

Parameter	Hair Test	Urinalysis
Marijuana Detection	Debatable efficiency, 7 to 37 days after use	Efficient hours to 30 days after use
Cocaine Detection	Efficient 7 to 37 days after use	Efficient hours to 3 days after use
Opiate Detection	Efficient 7 to 37 days after use	Efficient hours to 3 days after use
Amphetamine Detection	Efficient 7 to 37 days after use	Efficient hours to 3 days after use
Gaming Impact	Negligible	Vulnerable to many measures
Bias Toward Different Races	Detection suggests drug preference among races	Detection suggests drug preference among races
Impact on Deterrence	Effectiveness of test deters drug use	Deterrence limited by windows of detection/vulnerability to gaming
Cost Efficiency	Detection/deterrence levels suggest positive net benefits	Detection and deterrence levels suggest positive net losses

Notes: All days are approximate; using a 1.3cm specimen of hair

best method of testing. When all illicit drugs are equally targeted for detection in a random test, the data reviewed in this study suggests that the hair test would generate greater detection levels.

When deciding the best test method for detecting illicit drug use, a second factor necessary for consideration is the targeted time period of suspected use. The windows of detection analyzed in this thesis suggest that identification of recent drug use is best detected by the urinalysis whereas long-term drug use is best detected by the hair test. The testing premises, listed in Chapter II, provide nine reasons a Commanding Officer or Medical Officer may initiate a drug test. The table below lists the testing premises and identifies the testing method most appropriate for each premise. The window of detection of the hair test identifies drug use for a longer period than the urinalysis for a wide variety of addictive drugs. Whereas the hair test's large window of detection would identify a greater number of people who are drug dependent, urinalysis results indicate that a person, drug dependent or not, refrained from drug use within the past three days. Therefore, for purposes of recruit or officer candidate (ie ROTC, service academy, Officer Candidate School) screening, the hair test would be an optimal test to identify a history of drug abuse indicative of drug dependence or frequent drug abuse.

Furthermore, when conducting an inspection that does not target a specific period and is aimed at identifying drug use in general, the hair test covers a greater period than the urinalysis for all drugs, excluding marijuana. Although Table 18 identifies a variety of premises where the choice of tests is either a hair test or urinalysis, a tandem urinalysis and hair test would generate the best results in some situations.

Table 18. Optimal Test Choice for Premises

Premise	**Hair Test**	**Urinalysis**
Consent Test (Urinalysis)	Not suitable to confirm suspicion of recent use.	Recent use identified by urinalysis
Probable Cause (Urinalysis)	Not suitable to confirm suspicion of recent use	Recent use identified by urinalysis
Inspections (Hair Test)	Identifies a long term, non-specific 30 day period of use	Efficiently detects marijuana use; 3 day recent window on many drugs; vulnerable to gaming
Accession Testing (Hair Test)	Identifies drug a drug use period more representative of abuse and dependence	The period identified may or may not indicate frequent abuse or dependence
Command Directed (Hair Test/Urinalysis)	Dependent upon targeted period of suspicion	Dependent upon targeted period of suspicion
Physician Directed (Urinalysis)	Not suitable to confirm suspicion of recent use.	Recent use identified by urinalysis
Safety, Mishap, Accident (Hair Test)	Test can be initiated weeks after the event to determine drug use	Test must occur within days after the event to verify drug use
Rehabilitation/Treatment (Hair Test)	Single test can determine monthly use; suspicion of recent use constant for long periods	Suspicion of recent use constant for long periods requires multiple urinalyses to verify

Notes: Optimal test for each premise in parentheses

B. RECOMMENDATIONS

For further study it is recommended that other aspects of the feasibility of implementing the hair test be investigated, to include the ability of Department of Defense drug labs to convert to hair testing. It is beyond the scope of this study to

determine the feasibility of converting a drug-testing lab from urinalysis to hair testing. However, issues derived from investigating the ability of drug labs to convert to hair testing may have a significant impact on the time and plausibility of a change.

Further study in the areas of gaming among service members and under-reporting on the DODWWS is also necessary to better quantify the level of actual drug use among servicemen. Both gaming and under-reporting are often not considered in studies that investigate the effectiveness of drug testing. Yet gaming and under-reporting can significantly impact perceptions of drug use among servicemen and may serve to veil an illicit drug use problem. Hair tests can undercut a drug user's ability to game a drug test and will often verify the level of under-reporting that this thesis suggests. To better quantify the detection ability of the hair test relative to the urinalysis, a study that can quantify urinalysis gaming effectiveness and under-reporting among servicemen must first be conducted.

Recommended courses of action for the Marine Corps are listed below.

1. *Conduct a pilot hair test in tandem with a urinalysis.*

In doing so, the Marine Corps could develop a more accurate perception of the drug abuse habits among Marines. The results of such a test would 1) offer comparative data of the effectiveness of the hair test and urinalysis for a wide range of illicit drugs, 2) offer a more accurate representation of actual drug use for different drug types among Marines, 3) quantify the degree of under-reporting on the DODWWS, 4) investigate the efficiency and process of hair sample collection, 5) guide policy makers toward a decision on the best testing method.

2. *Perform a hair test on all recruits and officer candidates pursuing service.*

The hair test is the optimal method of determining drug dependence and chronic drug abuse. The hair test identifies cocaine, opiate, and amphetamine use much more effectively than the urinalysis. The number of chronic drug users and drug dependent entry-level personnel would likely significantly decline. If the Marine Corps can

effectively screen recruits and officer candidates for serious drug dependence and drug abuse habits, it would reduce the number of Marines who abuse drugs later in their careers.

3. Conduct one hair test annually on every active duty Marine.

In order to maintain an appreciable level of deterrence, the *threat* of having a random hair test must be sustained. Therefore, it should be mandated that each command perform a minimum of one hair test per year. The efficiency of the hair test would both identify current users and more importantly, deter possible users. In detecting cocaine, opiates, and amphetamines, one random hair test would equate with approximately ten random urinalyses. In addition, those being sampled would not be able to game a hair test as readily as a urinalysis. The hair test would be a more accurate method of detecting common and dangerous drugs than the urinalysis.

C. LIMITATIONS

This study only suggests general estimations, based upon the data provided by previous studies. Although literature is available for the detection, deterrence, and cost estimates of the Navy/Marine Corps urinalysis program, there are no substantive studies that investigate hair testing in the Navy or Marine Corps. Accordingly, estimates of deterrence, detection, and cost of the hair test may not represent actual values if the hair test were implemented in the Marine Corps today. Additionally, this study focused only on four criteria that defined feasibility, assuming that other criteria were met. Some of these assumptions are: the Navy drug laboratories could support hair testing; hair could be collected from every individual; an efficient standard testing procedure was approved; and drug use habits among Marines would be relatively stable from year to year.

D. CONCLUSIONS

This study has presented and developed several important aspects of the hair test that suggest the hair test is a feasible method of detecting illicit drug use among Marines in a fair and efficient manner. This study is unique, as it investigates detection,

deterrence, racial bias, and costs of the hair test while presenting these aspects in the perspective of the hair test's utility in the Marine Corps. The beneficial aspects of the hair test could dramatically change drug testing paradigms and assumptions that are currently well rooted in the Navy/Marine Corps urinalysis program. This thesis has illustrated that the hair test detection results may far surpass the results of the urinalysis if implemented in the Marine Corps. These detection results may uncover veiled drug use habits among Marines and may consequently uncover a drug use problem currently unexposed by the urinalysis.

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